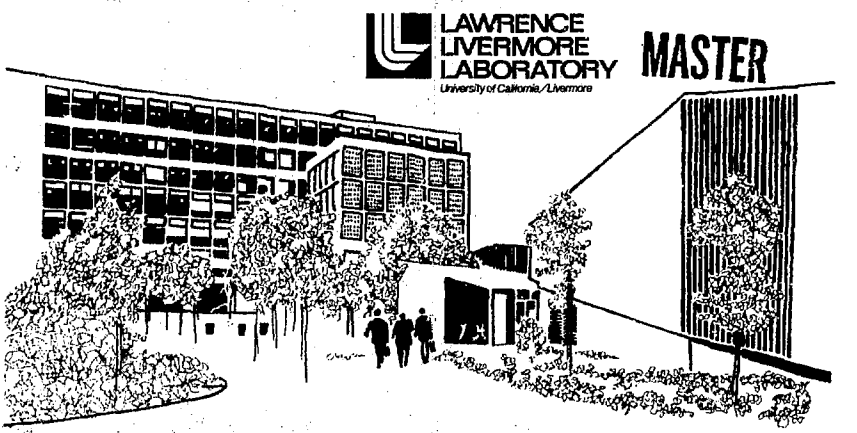
UCRL-51718

FAULT TREE ANALYSIS OF THE LPTR SCRAM SYSTEM

W. Keith Mortensen
Jack W. Savage

December 13, 1974

Prepared for U.S. Energy Research & Development Administration under contract No. W-7405-Eng-48



Printed in the United States of America
Available from
National Technical Information Service
U. S. Department of Commerce
5285 Port Royal Road
Springfield, Virginia 22151
Price: Printed Copy $___*; Microfiche $2.25

*Pages	NTIS Selling Price
1-50	$4.00
51-150	$5.45
151-325	$7.60
326-500	$10.60
501-1000	$13.60

Distribution Category
UC-78b

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Contents

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Abstract

The protective control or scram system of the Livermore Pool Type Reactor (LPTR) has been subjected to fault tree analysis to determine its vulnerability to various component failures or other untoward events both credible and incredible. This report describes the analysis and discusses the results. The principal result is that no single component failure nor any single credible event can result in a failure of the reactor to scram when a scram is required.

Introduction

The Livermore Pool Type Reactor (LPTR) is a scientific research reactor used primarily as a source of neutrons for irradiation experiments. It is designed to operate at a maximum power level of 3 MW thermal. A detailed description of the reactor and its protection system is given in the LPTR Safety Analysis Report.[1]

The staff at LPTR performed the fault tree analysis described here to determine whether the scram system could withstand a single failure and still shut down the reactor. As a result of our analysis we conclude that no single component failure nor any single credible event can result in a failure of the reactor to scram when a scram is required.

The appendices to the report include control system diagrams for the LPTR, diagrams of the fault tree analyzed in this study, and results of the computer analysis of the fault tree.

The LPTR Control System

The reactor is brought to its operating power of 3 MW thermal by manually positioning four shim rods to achieve the desired criticality and balance in the reactor core. The power is then automatically regulated by a fifth regulating rod.

Reactor shutdown is accomplished by inserting the four shim rods into the core. Any two shim rods fully entering the core insert sufficient negative reactivity to shut the reactor down.

The shim rods are coupled to the rod drive assemblies by sensitive

1. Safety Analysis Report for the Livermore Pool Type Reactor, Lawrence Livermore Laboratory, Rept. UCRL-5142J (Sept. 18, 1974).

electromagnets. When a magnet is de-energized the associated shim rod falls by force of gravity back into the core. Each magnet is powered by a separate dc power supply and driven by a separate vacuum-tube amplifier. The safety interlock chain (shown on page 24 of the control system drawings, Appendix A) removes the ac power from all four magnet power supplies through the contacts of relay 62.

The magnet amplifiers control the current at the negative terminals of the magnets. The inputs to the four magnet amplifiers are tied to a common bus called the sigma bus. The sigma bus is driven by four independent sigma amplifiers, any one of which will drive the four magnet amplifiers to cutoff. Three of these sigma amplifiers sense power level, resulting in a scram at a power level of 4.5 MW. The fourth sigma amplifier initiates a scram when the period is less than 1 sec.

The block diagram of reactor nuclear instrumentation is shown in Fig. 1. Figure 2 shows how the sigma bus and associated amplifiers are interconnected.

Included for reference in Appendix A are pages 8, 13, 14, and 24 of Dwg. No. LEA-01-3154-01, the drawings of the control system for the LPTR, which contain the circuits for the safety interlock chain and the associated relay coils.

Fault Tree Analysis of the Control System

Fault tree analysis is a technique by which computers can be used to determine which faults and which combinations of faults can result in a particular system failure. References 2 and 3 discuss the fault tree analysis method in more detail.

In this report the system failure event of interest is: three or more shim rods fail to fully enter the core when a scram condition exists. This is called the "top event."

The analysis is accomplished by drawing a fault tree model which uses a logic symbol format to represent the sensing and control functions of the reactivity control system of the reactor as they relate to the top event. Five symbols make up the fault tree: "and" gates, "or" gates, circles, diamonds, and houses (see Fig. 3).

An "and" gate requires that all inputs to it be satisfied before an output from it will occur.

An "or" gate requires only that one or more of the inputs to it be satisfied before an output from it will occur.

A circle represents a component primary failure, which is sufficient to actuate an input to a gate. The meaning of "component" is subject to definition to suit the case being analyzed, but in all cases it is the final termination of a particular branch of the fault tree, as

2. D. F. Haasl, "Advanced Concepts in Fault Tree Analysis," In System Safety Symposium, June 8-9, 1965 (The Boeing Company, Seattle, Washington, 1965).

3. M. E. Stewart et al., Reliability Analysis of the Power Burst Facility Reactor Protection System, Idaho Nuclear Corporation, Idaho Falls, Idaho (Dec. 1969).

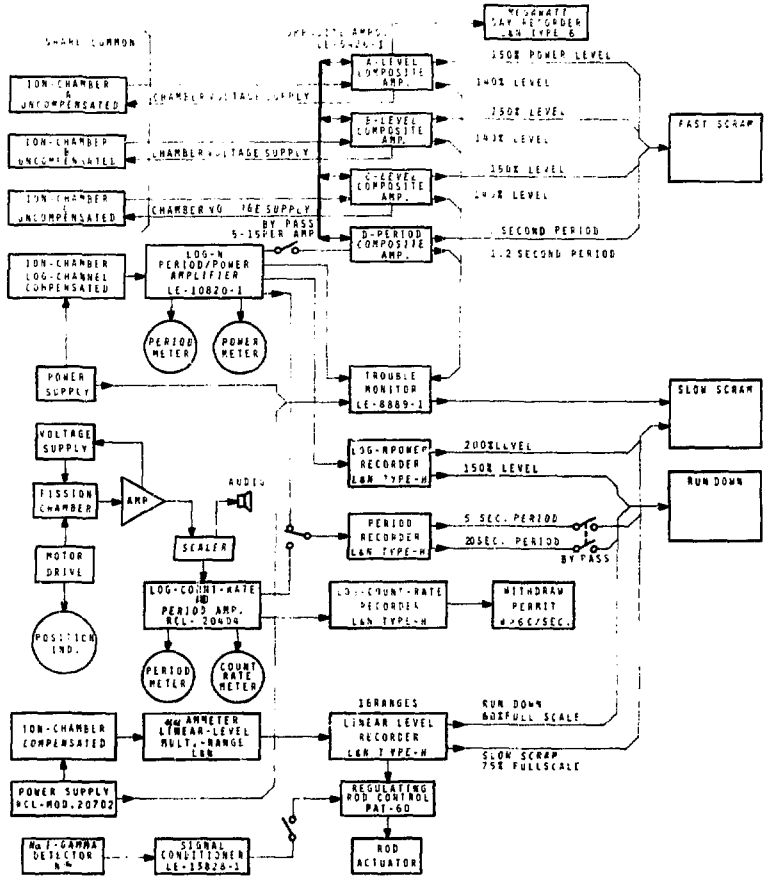


Fig. 1. Block diagram of LPTR nuclear instrumentation.

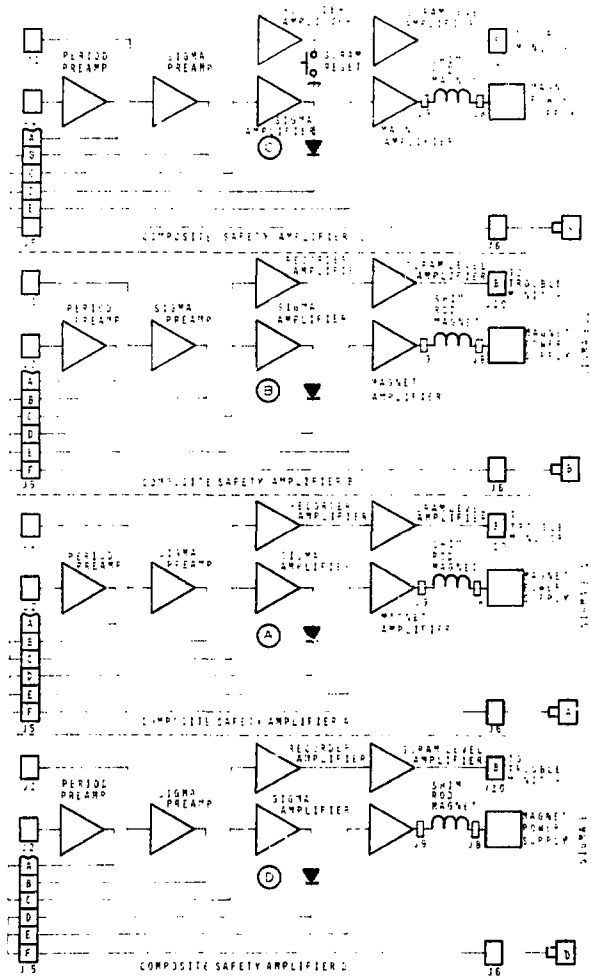


Fig. 2. Interconnection of sigma bus and associated amplifiers.

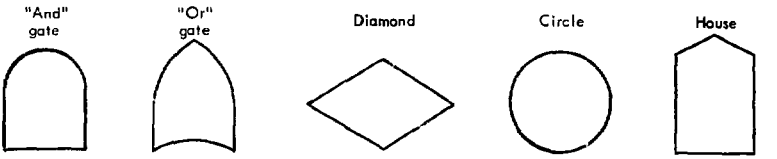


Fig. 3. Symbols used in fault tree analysis.

determined by the desired degree of resolution of the analysis. For example, a circle may represent a single component or even a subcomponent, such as the coil of a relay, while a second circle may represent the contacts. Or one circle may represent the normally open contacts, while another may represent the normally closed contacts. In another case a circle may represent an entire amplifier or even a system consisting of amplifier, detector, and power supply. In general, circles represent components or systems which may fail to perform their intended functions when needed.

A diamond is similar to a circle in that it represents an event which is sufficient to actuate an input to a gate, and is also the termination of a particular branch of the tree. It differs, however, in that it represents a chassis, a subsystem, an open- or short-circuit wiring fault, a circuit discontinuity, a human action, or other event for which the analysis is truncated before there is sufficient detail developed for it to be represented by the additional tree branches which would ultimately end in primary fault circles. The desired degree of resolution dictates when a particular branch can be terminated in a diamond.

Diamonds on the fault tree represent unusual failures or abnormal occurrences. Examples are a short circuit to a voltage source, operator error, and failures requiring limiting conditions in order to result in a fault. Some diamonds represent events which are considered to be incredible. Each diamond is explained by a numbered diamond note.

Houses in the tree are used as switches to enable or disable portions of the tree, depending upon which scram conditions exist in the analysis being conducted. Each scram condition can be enabled individually, or several may be enabled simultaneously. For example, one may expect that both fast period and high power may exist simultaneously. There are 49 house inputs which serve as switches to enable the various scram conditions.

The fault tree is so constructed that it can represent the scram system for any combination of scram conditions. Table 1 lists each of the possible scram conditions. These may occur singly or in combinations of two or more occurring simultaneously. (Some are mutually exclusive, and some are included automatically as part of another scram condition.) Table 2 lists the house conditions which were included in the rates input portion of the data cards for this study to simulate 17 scram conditions for which computer runs were made.

Table 1. Scram conditions and mechanisms of the LPTR.

Condition causing scram	Mechanism producing scram
Fast scrams	
Power ≥4.5 MW	Sigma bus
Period ≤1 sec	Sigma bus
Slow scrams	
Power ≥6 MW (log N)	RE-85[a]
Power ≥4.2 MW:	
Safety amp A	RE-81
Safety amp B	RE-80
Safety amp C	RE-82
Period ≤1.2 sec (safety amp D)	RE-83
Period ≤5 sec (period recorder)	RE-84
Power ≥75% of linear recorder scale	RE-85
Primary coolant flow low	RE-75
Experiment scram	RE-32
Amplifier or power supply troubles	RE-16, -17, -18, -19 in trouble monitor
Rod drop test	RE-2 in rod drop tester
Pool level low	RE-60
Primary coolant temperature high	RE-2 in primary coolant temperature monitor
Scram button pushed	PB-1[b]

[a]RE denotes relay.

[b]PB denotes push button.

Detailed diagrams of the fault tree analyzed in this study are given in Appendix B.

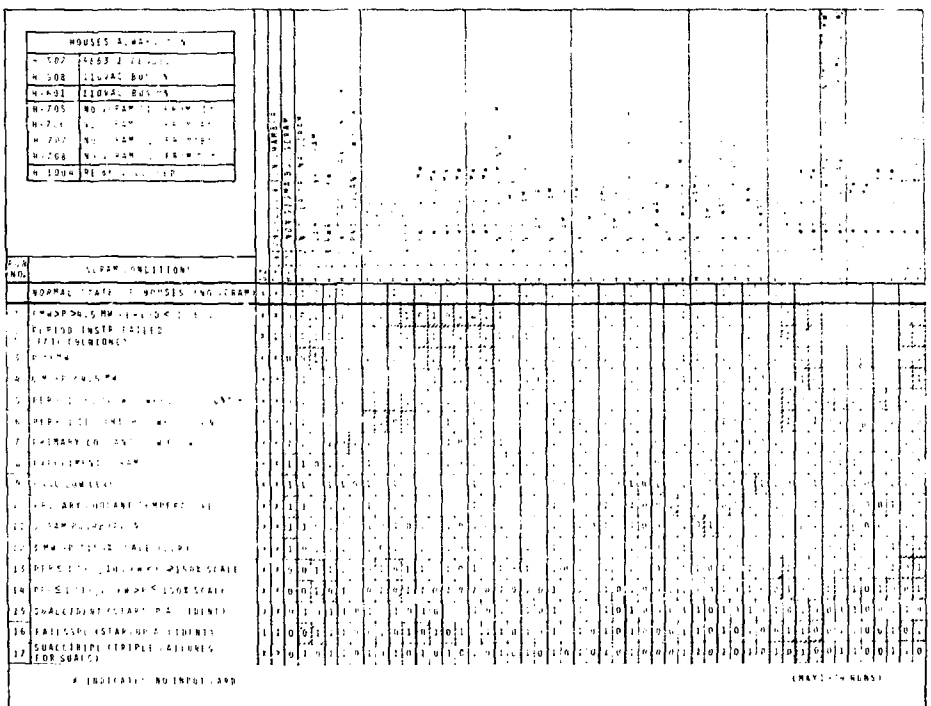
The primary objective of this analysis is to show that the reactor can experience the prescribed startup accident and still withstand one additional failure. The conditions for the prescribed startup accident are set forth in Sec. 15.2.2 of the LPTR Safety Analysis Report[1] as follows:

1. The reactor is initially shut down.
2. The shim rods are withdrawn simultaneously at their maximum rate.
3. All period and high level scrams and rundowns fail except the level-safety fast scram at 150% of full power.
4. The shim rods continue out for 20 msec (the measured delay time) after the 150% power level has been reached and then fall into the core with an acceleration of 5.2 m/s^2.

Simulation of the startup accident as defined above is readily accomplished in either of two ways:

1. All houses representing power ≥4.5 MW are turned on (tau set equal to 1), and all houses representing period

Table 2. Rates input conditions for computer runs.



≤5 sec are also turned on. Diamond D-200 and component C9LNIONC, which represents the log N compensated ion chamber, are turned on. This effectively falls all period and slow scrams (run-downs are not included in the fault tree analysis of the scram system), leaving only the 4.5-MW fast scram (150% of full power) to scram the reactor (see computer run 16, Appendix C).

2. A second method is to enable only one scram condition, i.e., house 702 representing power ≥4.5 MW. (House 704, the complement of house 702, is also turned off.) This effectively bypasses all scrams except the level-safety fast scram at 150% of full power (computer run 15, Appendix C).

Both computer runs were made and the results for both were identical, as predicted.

For the startup accident prescribed in Sec. 15.2.2 of the LPTR Safety Analysis Report,[1] there are two single events, either of which will result in the top event, i.e., cause two or more shim rods to fail to fully enter the core; these are diamonds D-100 and D-702. Each of these events is considered to be outside the limits of credible events. (See diamond notes 2 and 8, in Appendix B.)

Conclusion

There are no single component failures which can result in failure of the reactor to scram for the prescribed startup accident. There are also no pairs of components which can result in failure to scram.

As a minimum, failure of three independent components — one in each of the three level-safety fast scram channels — would be required to produce a scram failure that could result in release of fission products within the reactor containment dome.

Appendix A. *Control System Diagrams for the LPTR*

Reproduced here are pages 8, 13, 14, and 24 of the LEA-01-3154-01 series of drawings of the LPTR control system:

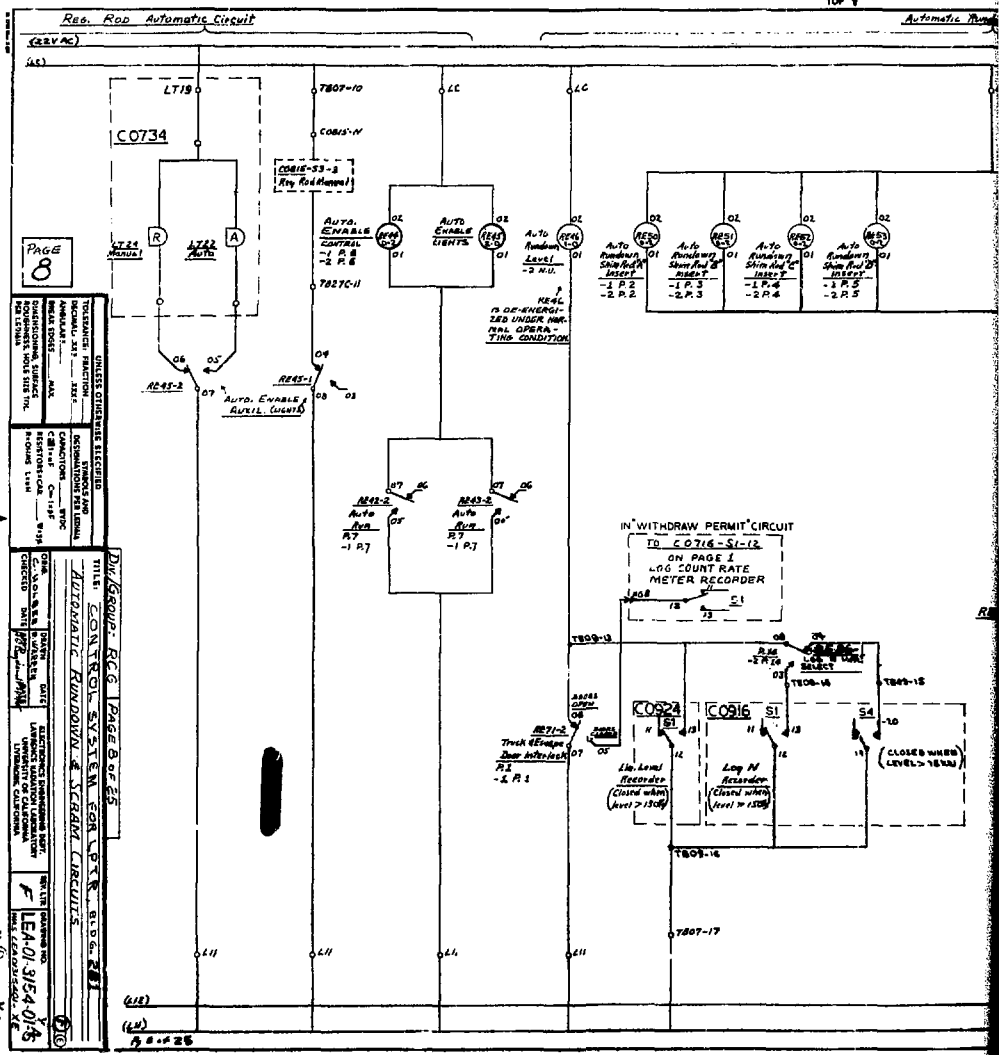
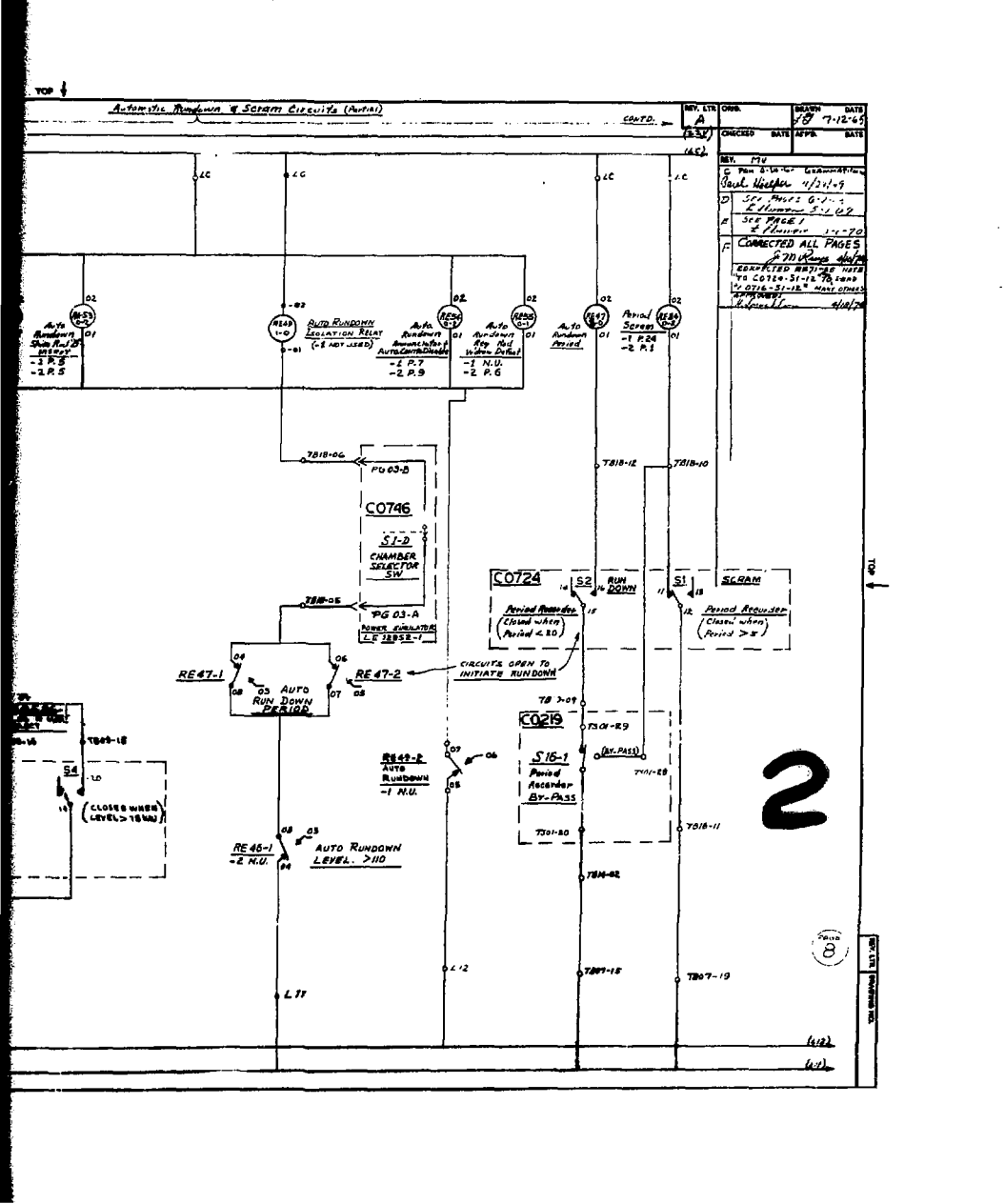
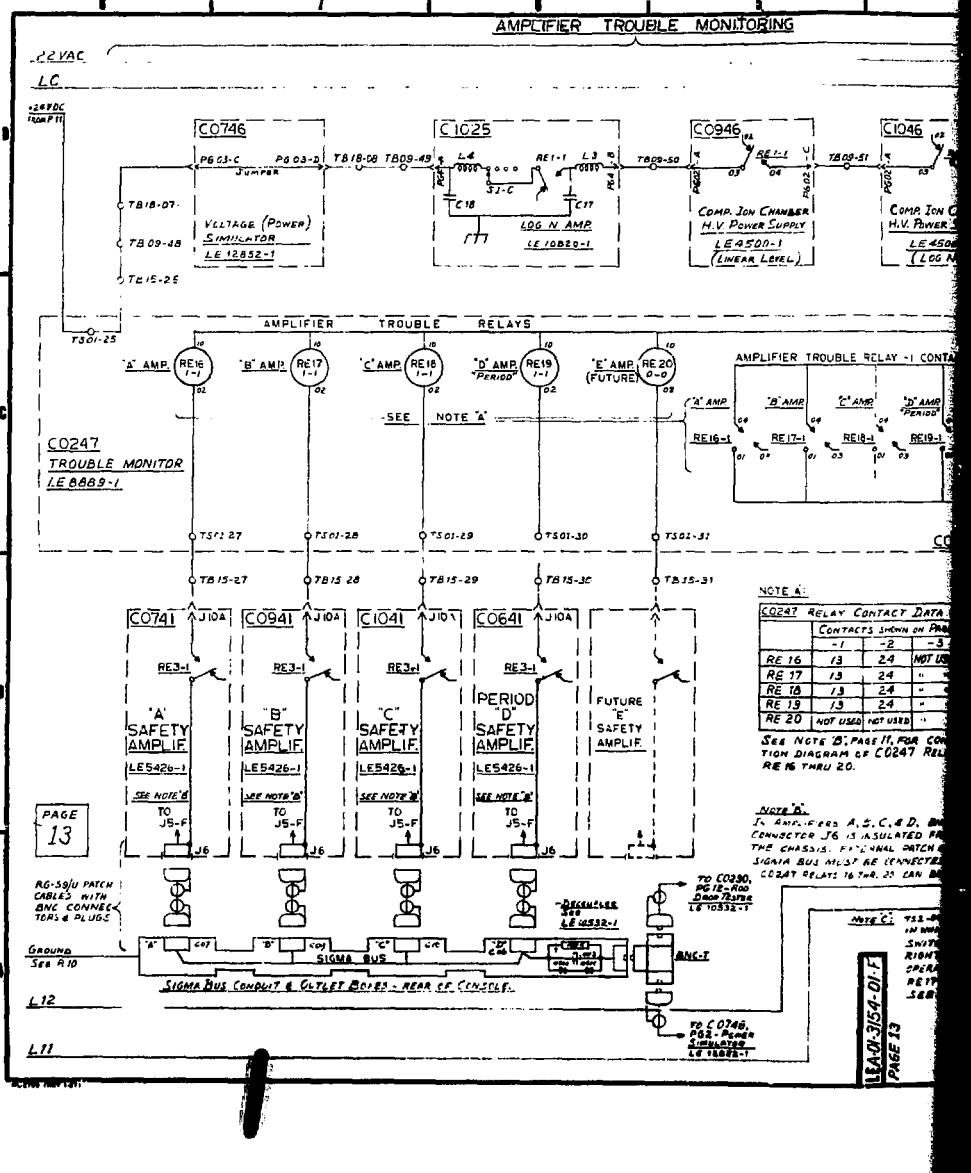


Fig. A-1. Automatic rundown and scram circuits (p. 8).


Automatic Rundown & Scram Circuits (Partial)
CONTD.
REV. LTR. A
DRAWN 7-12-65
CHECKED
APPR.
REV. 7-14
Paul Hooper 11/21-69
SEE PAGES G-1-1 & E Planning S-1-02
SEE PAGE 1 & Planning 1-1-70
CORRECTED ALL PAGES
CORRECTED REVISE DATE TO C0720-51-15 & 1200 & C 0716-51-15 MADE OTHER
APPROVED 4/8/70
LC
Auto Rundown Shim Rod 25 steps -1 K 5 -2 K 5
RE49 1-0 AUTO RUNDOWN ISOLATION RELAY (-2 NOT USED)
RE50 0-1 Auto Rundown Annunciator & Auto Control Disable -1 P.7 -2 P.9
RE50 0-1 Auto Rundown Rod Hold Window Defeat -1 N.U. -2 P.6
RE47 0-1 Auto Rundown Permit
RE48 0-1 Period Screen -1 P.24 -2 P.1
7818-06
7818-12
7818-10
PG 03-B
C0746
S1-D CHAMBER SELECTOR SW
7818-05
PG 03-A
POWER SUMULATOR LF 1852-1
C0724
S2 RUN DOWN
S1 SCRAM
Period Recorder (Closed when Period < 20)
Period Recorder (Closed when Period > 5)
RE47-1
RE47-2
AUTO RUN DOWN PERIOD
CIRCUITS OPEN TO INITIATE RUNDOWN
TB 7-09
C0219
S16-1 Period Recorder By-Pass
7301-29
(BY-PASS)
7701-29
7301-30
7818-11
RE49-2 AUTO RUNDOWN -1 N.U.
RE46-1 -2 N.U.
AUTO RUNDOWN LEVEL > 110
7814-02
7849-18
S4
(CLOSES WHEN LEVEL > 15 IN.)
L 12
L 77
7807-18
7807-19
2
(8)
REV. LTR.
DRAWING NO.


AMPLIFIER TROUBLE MONITORING
22 VAC
LC
+24 VDC FROM P11
C0746
P603-C
P603-D
JUMPER
TB18-08
TB09-49
TB18-07
TB09-48
TB15-25
VOLTAGE (POWER) SIMULATOR
LE 12852-1
C1025
L4
L3
RE1-1
TB09-50
J3-C
C18
C17
LOG N AMP
LE 10820-1
C0946
P602
TB09-51
COMP. ION CHAMBER H.V. POWER SUPPLY
LE 4500-1
(LINEAR LEVEL)
C1046
COMP. ION C
H.V. POWER
LE 450
(LOG N
TS01-25
AMPLIFIER TROUBLE RELAYS
"A" AMP.
RE16 1-1
"B" AMP.
RE17 1-1
"C" AMP.
RE18 1-1
"D" AMP. "PERIOD"
RE19 1-1
"E" AMP. (FUTURE)
RE20 0-0
AMPLIFIER TROUBLE RELAY -1 CONTA
"A" AMP
"B" AMP
"C" AMP
"D" AMP "PERIOD"
RE16-1
RE17-1
RE18-1
RE19-1
SEE NOTE "A"
C0247
TROUBLE MONITOR
LE 8889-1
TS01-27
TS01-28
TS01-29
TS01-30
TS01-31
TB15-27
TB15-28
TB15-29
TB15-30
TB15-31
C0741
C0941
C1041
C0641
J10A
RE3-1
"A" SAFETY AMPLIF.
"B" SAFETY AMPLIF.
"C" SAFETY AMPLIF.
PERIOD "D" SAFETY AMPLIF.
FUTURE "E" SAFETY AMPLIF.
LE5426-1
SEE NOTE 'B'
TO J5-F
J6
PAGE 13
RG-59/U PATCH CABLES WITH BNC CONNECTORS & PLUGS
GROUND SEE A10
SIGMA BUS
SIGMA BUS CONDUIT & OUTLET BOXES - REAR OF CONSOLE.
DECOUPLER SEE LE 10532-1
TO C0230, PG 12-Rod DROP TESTER LE 10532-1
BNC-T
TO C0746, PG2-Bender SIMULATOR LE 15092-1
L12
L11
NOTE 'A':
C0247 RELAY CONTACT DATA
CONTACTS SHOWN ON PAN
-1
-2
-3
RE 16 13 24 NOT US
RE 17 13 24 "
RE 18 13 24 "
RE 19 13 24 "
RE 20 NOT USED NOT USED "
SEE NOTE 'B' PAGE 11, FOR CO
TION DIAGRAM OF C0247 REL
RE 16 THRU 20.
NOTE 'B':
J1 AMPLIFIERS A, B, C, & D.
CONNECTOR J6 IS INSULATED FR
THE CHASSIS. EXTERNAL PATCH C
SIGMA BUS MUST BE CONNECTED
C0247 RELAYS 16 THR. 20 CAN
NOTE 'C':
TS2-
IN WHI
SWITC
RIGHT
OPERA
RE 17
SEE
LEAV-3154-01-F
PAGE 13

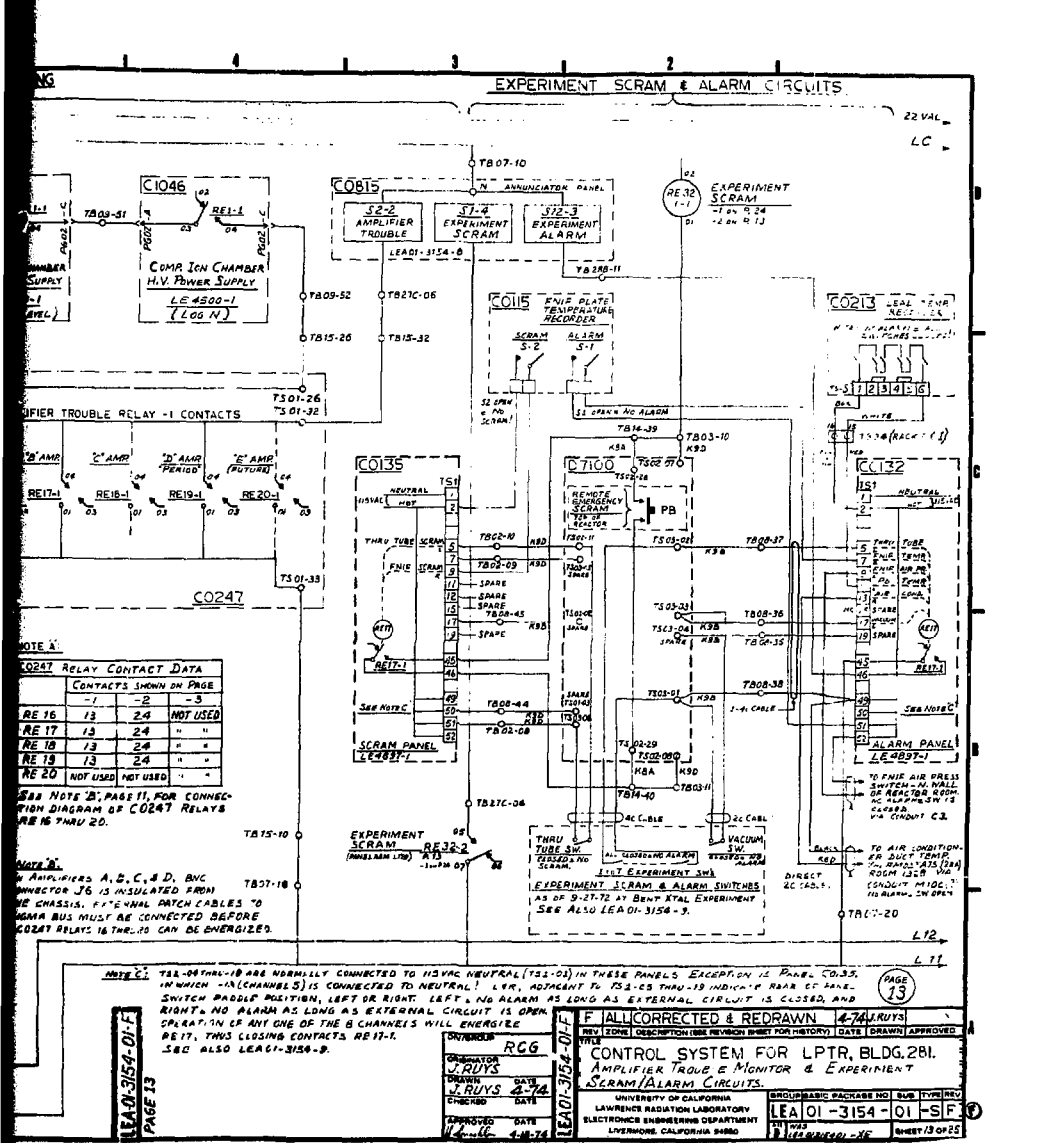


Fig. A-2. Amplifier trouble monitor and experiment alarm circuit (p. 13).

MONITORING, ALARM, & SCRAM CIRC

LEVEL & PERIOD SAFETY AMPLIFIERS

22 VAC

LC

LEVEL SAFETY SCRAM

SAFETY AMPLIFIERS - LE 5624-1

C0741 "A"

C0941 "B"

C1041 "C"

C0641 "D" PERIOD

C "E" (FUTURE)

PG 9

PG 10

TB15-36 TB15-37 TB15-38 TB15-39 TB15-40 TB15-41 TB15-42 TB15-43 TB15-44 TB15-45

C0247

TS01-36 TS01-37 TS01-38 TS01-39 TS01-40 TS01-41 TS01-42 TS01-43 TS01-44 TS01-45

RE21 1-0 "A"

RE22 1-0 "B"

RE23 1-0 "C"

RE24 1-0 "D" PERIOD

RE25 1-0 "E" (FUTURE)

RE80 "A" C-2

RE81 "B" 0-2

RE82 "C" 0-2

TB15-45 TB15-30 TB15-46

TROUBLE MONITOR - LEVEL SAFETY RELAYS

See Note "A"

TS01-50

TS01-49

TS01-48

TS01-47

TS01-46

"A" RE21-1

"B" RE22-1

"C" RE23-1

PERIOD "D" RE24-1

FUTURE "E" RE25-1

C0219

TS2-30

BY-PASS

TS01-02

LE 5669-1 C0247

TB13-02 TB14-03 TB07-25

L12

L11

PAGE 14

NOTE "A"
CONT. TROUBLE MONITOR - LE 5669-1
RE 21 Thru RE 25
CK-POWER-1869
4PDT
Potter & Brumfield KRP-11AG-120
PLATE RELAY

E A 0 - 3 E 4 - 0 I F
Page 76

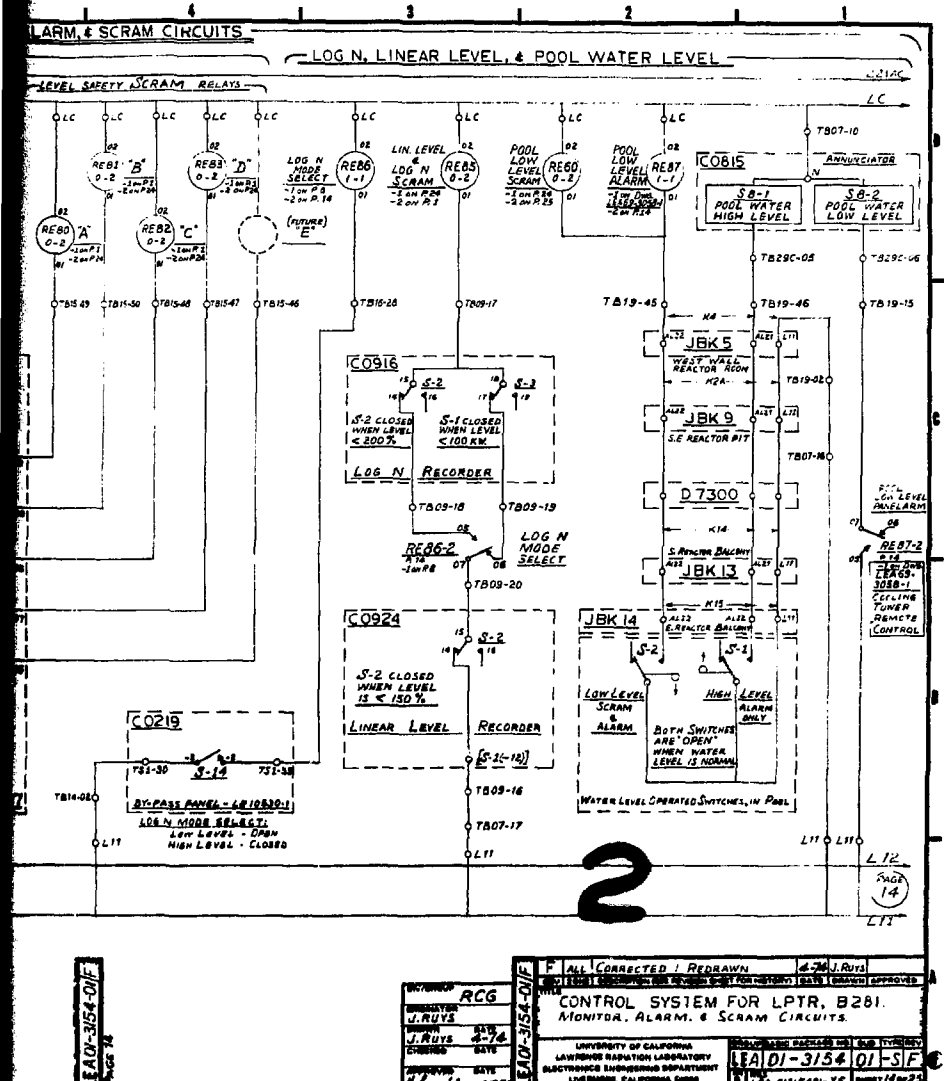
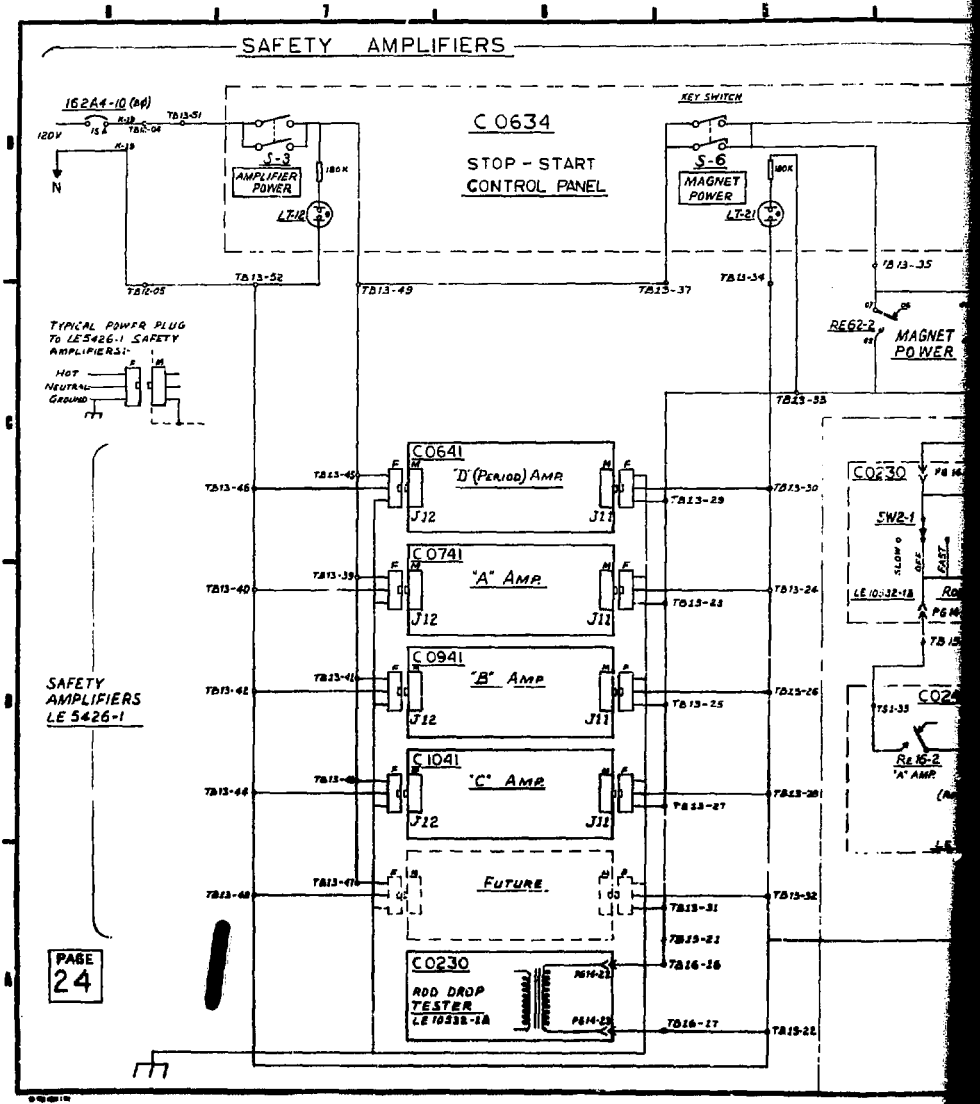


Fig. A-3, Monitor alarm and scram circuits (p. 14).


SAFETY AMPLIFIERS
162A4-10 (B4)
120V
N
TB13-51
TB12-04
TB12-05
TB13-52
TB13-49
TB13-37
TB13-34
TB13-35
C0634
STOP - START
CONTROL PANEL
S-3
AMPLIFIER POWER
LT-12
180K
KEY SWITCH
S-6
MAGNET POWER
LT-21
180K
REG2-2
MAGNET POWER
TYPICAL POWER PLUG TO LE5426-1 SAFETY AMPLIFIERS:-
HOT
NEUTRAL
GROUND
TB13-55
C0641
"D" (PERIOD) AMP
J12
J11
C0741
"A" AMP
J12
J11
C0941
"B" AMP
J12
J11
C1041
"C" AMP
J12
J11
FUTURE
TB13-45
TB13-39
TB13-42
TB13-48
TB13-47
TB13-30
TB13-29
TB13-24
TB13-23
TB13-26
TB13-25
TB13-28
TB13-27
TB13-32
TB13-31
TB13-21
TB16-16
TB16-17
TB15-22
C0230
ROD DROP TESTER
LE10538-1A
P614-22
P614-23
SAFETY AMPLIFIERS LE5426-1
PAGE 24
SW2-1
SLOW
OFF
FAST
LE10-32-1B
TB13-33
Re15-2
"A" AMP

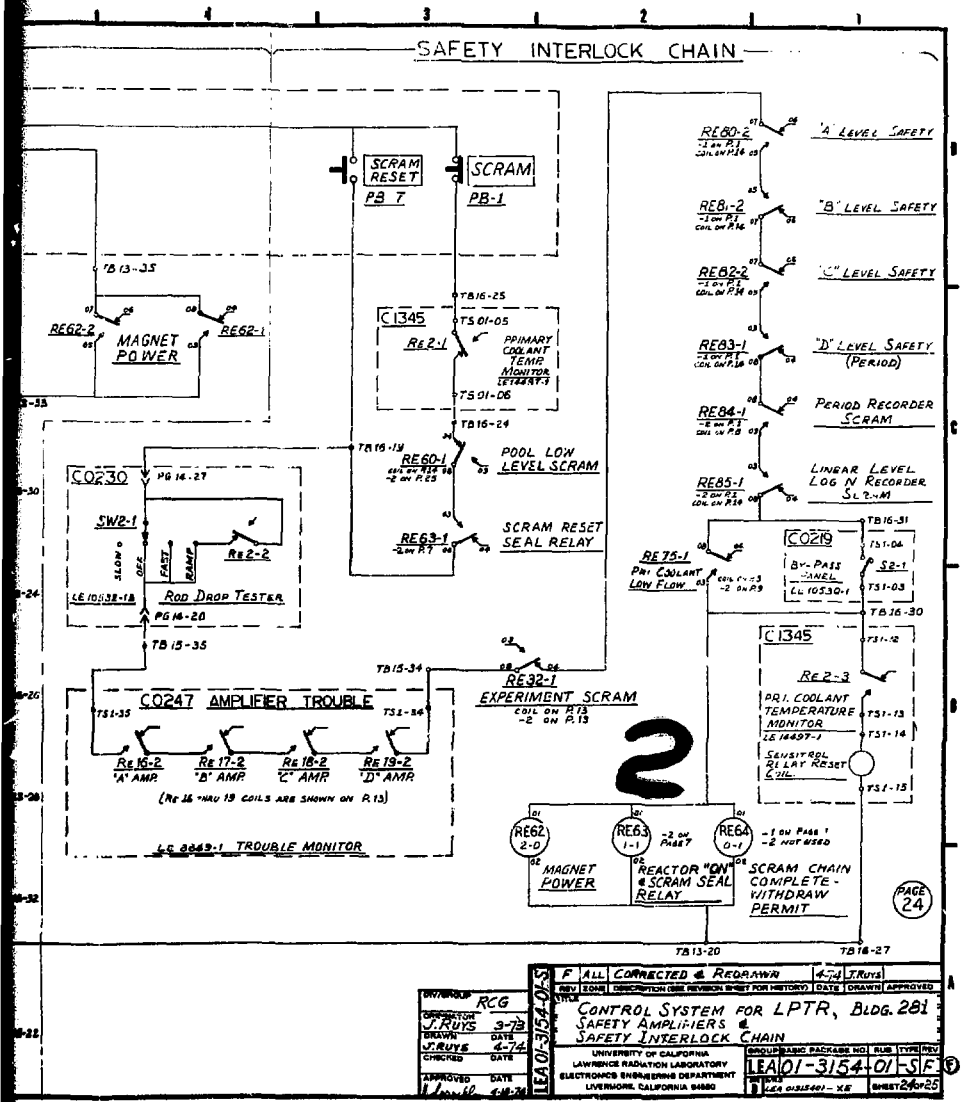
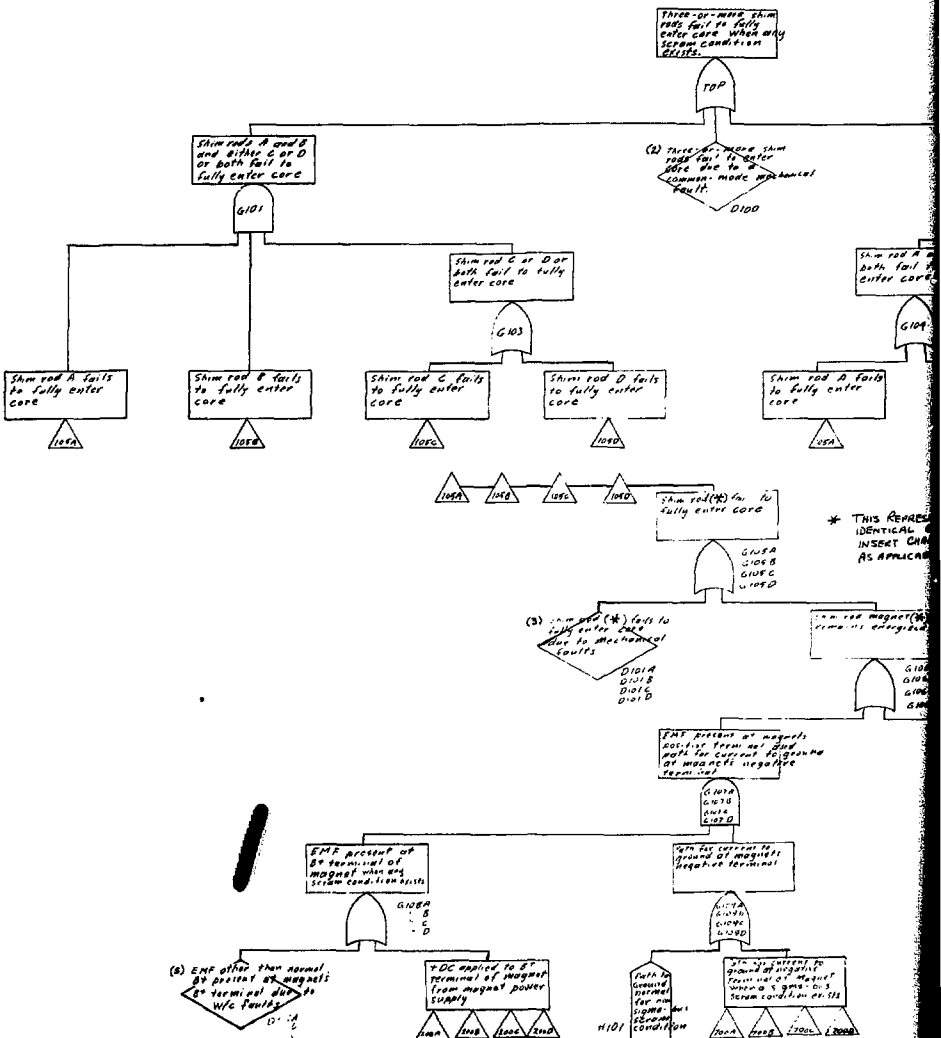
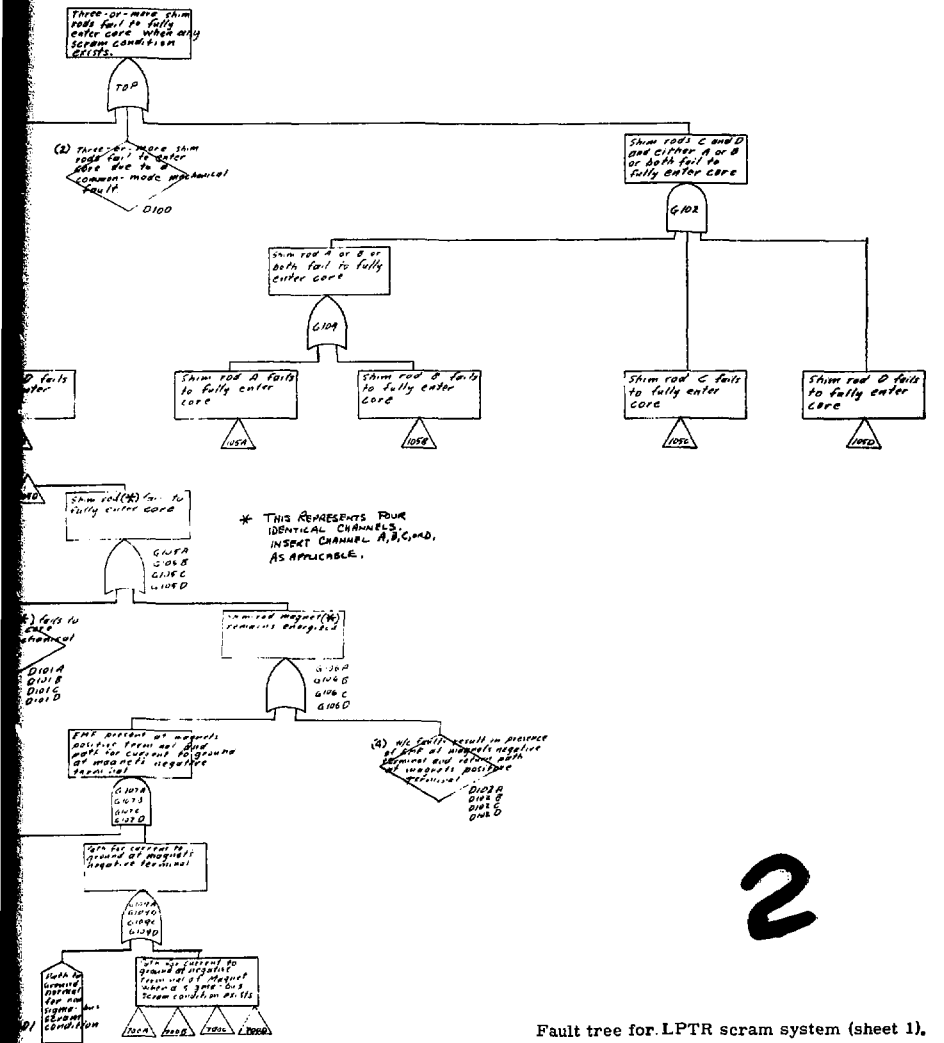


Fig. A-4. Safety amplifiers and safety interlock chain (p. 24).

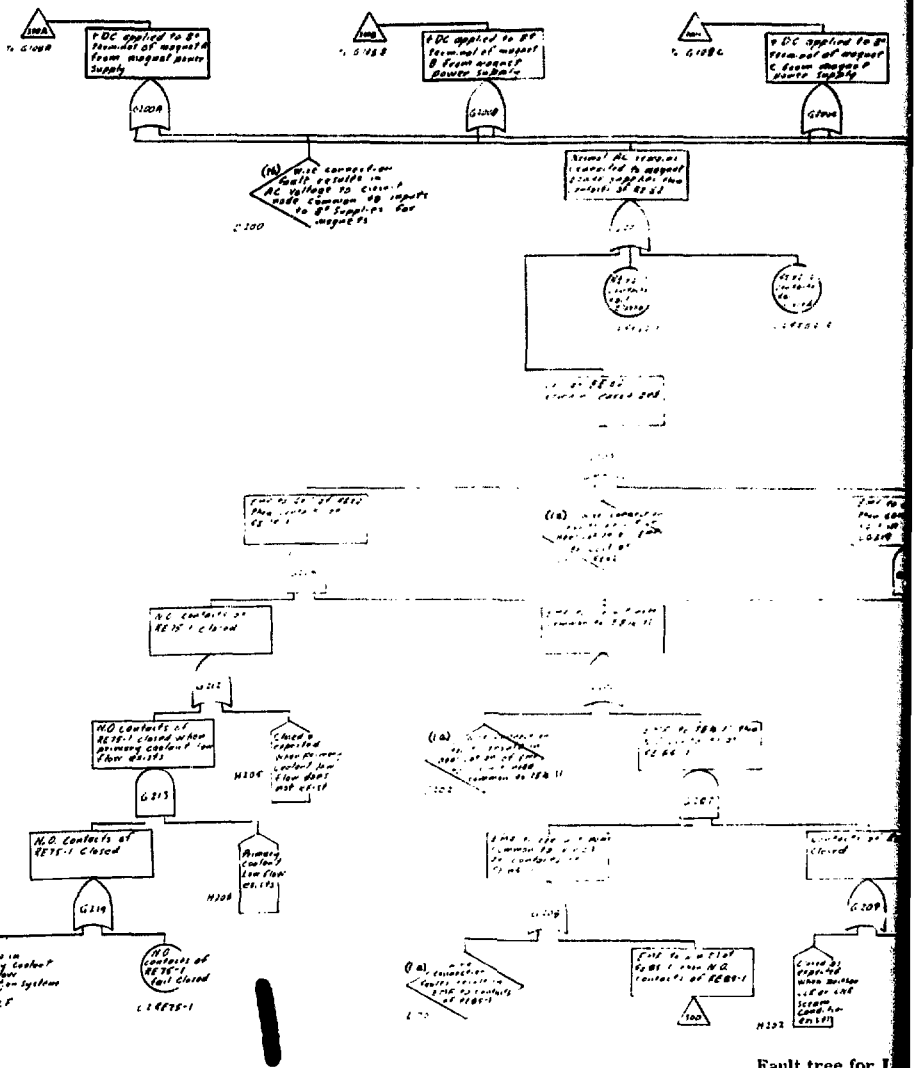
Appendix B. Fault Tree Analyzed in This Study

The fault tree analyzed in this study is diagrammed on the following 11 pages, labeled sheets 1 through 11. Numbers in parenthesis by the diamonds refer to "diamond notes" which are listed beginning on p. 26.

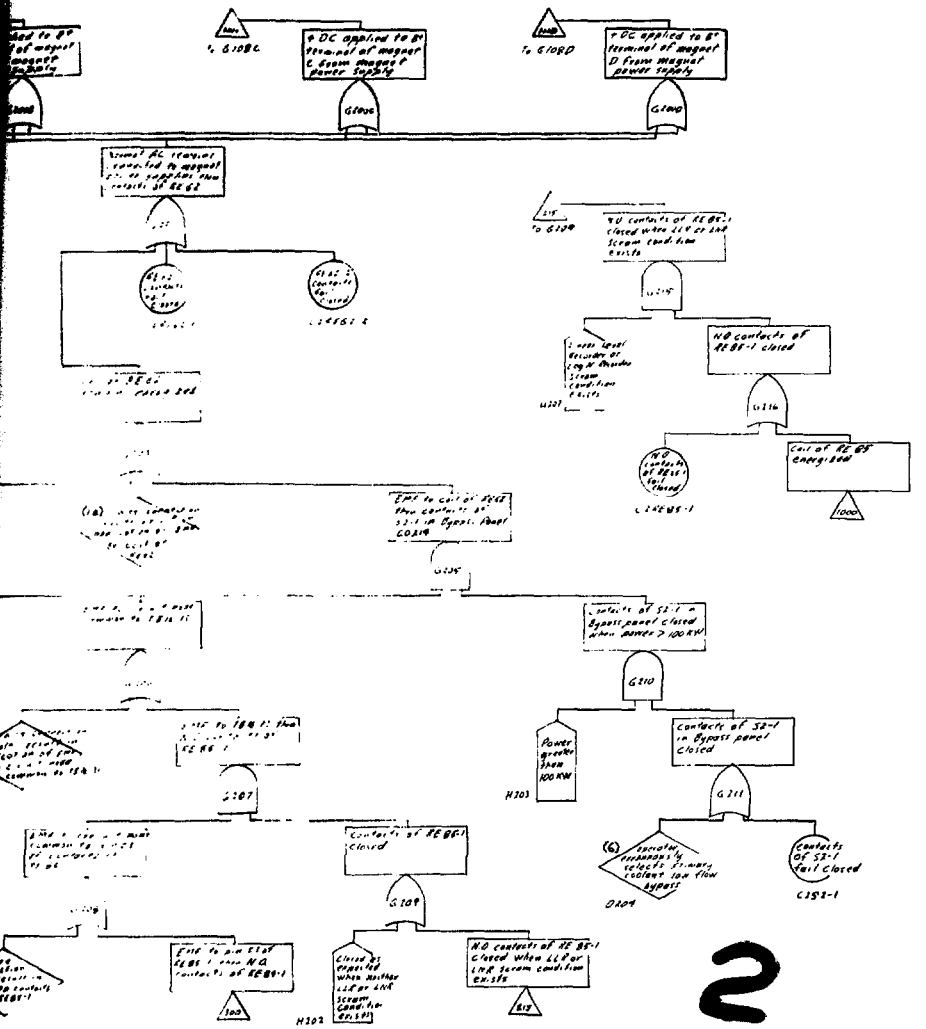

Three-or-more shim rods fail to fully enter core when any scram condition exists.
TOP
Shim rods A and B and either C or D or both fail to fully enter core
G101
(2) Three-or-more shim rods fail to enter core due to a common-mode mechanical fault.
D100
Shim rod C or D or both fail to fully enter core
G103
Shim rod A fails to fully enter core
105A
Shim rod B fails to fully enter core
105B
Shim rod C fails to fully enter core
105C
Shim rod D fails to fully enter core
105D
Shim rod A fails to fully enter core
105A
G104
105A
105B
105C
105D
Shim rod (*) fail to fully enter core
G105A
G105B
G105C
G105D
* THIS REPRE
IDENTICAL
INSERT CHA
AS APPLICA
(3) Shim rod (*) fails to fully enter core due to mechanical faults
D101A
D101B
D101C
D101D
EMF present at magnets positive terminal but path for current to ground at magnet negative terminal
G107A
G107B
G107C
G107D
EMF present at B+ terminal of magnet when any scram condition exists
G108A
B
C
D
Path for current to ground at magnet negative terminal
G109A
G109B
G109C
G109D
(8) EMF other than normal B+ present at magnets B+ terminal due to W/C faults
D
A
C
B
+DC applied to B+ terminal of magnet from magnet power supply
110A
110B
110C
110D
Path to Ground Internal for min signal for scram condition
H101
Path of current to ground at negative terminal of magnet when a scram occurs for this scram condition
200A
200B
200C
200D



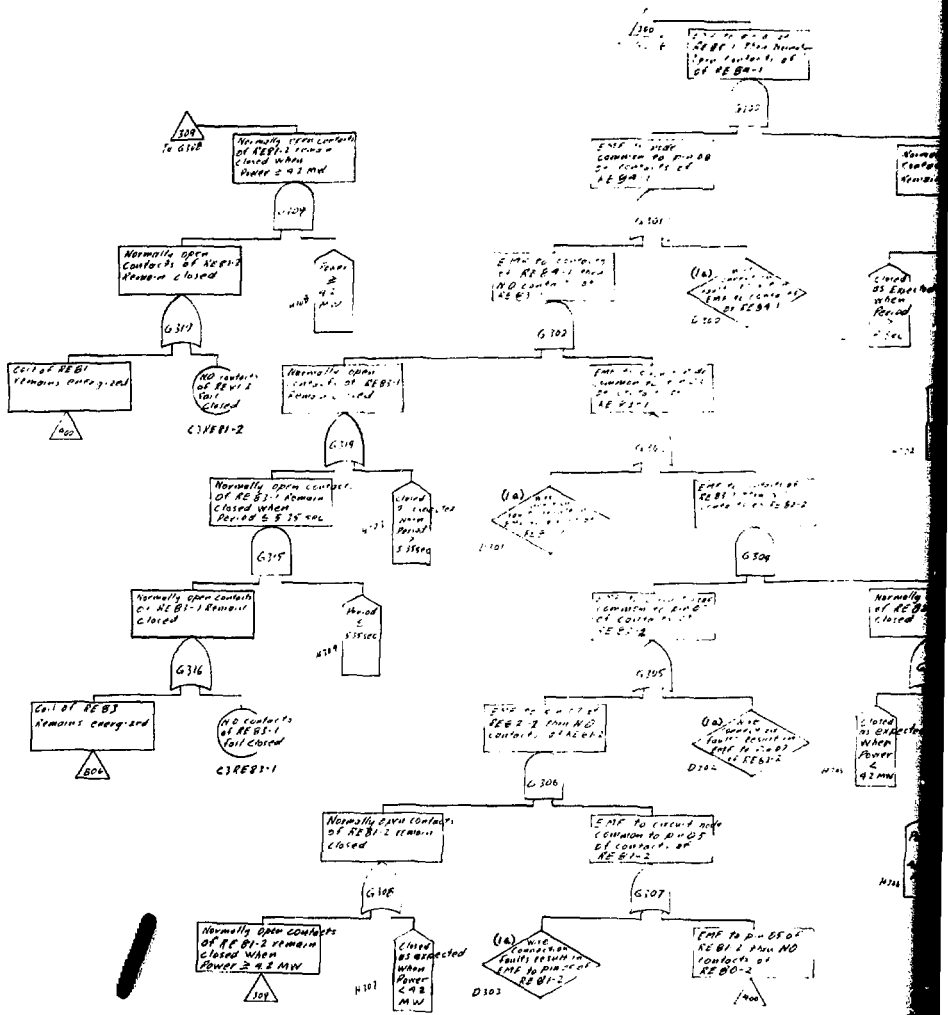
Fault tree for LPTR scram system (sheet 1).



Fault tree for L



Fault tree for LPTR scram system (sheet 2).


309
To G108
Normally open contacts of RE81-2 remain closed when Power ≥ 92 MW
Normally open contacts of RE81-2 Remain closed
Power ≥ 92 MW
G317
Coil of RE81 remains energized
NO contacts of RE81-2 fail closed
C3RE81-2
Normally open contacts of RE81-1 Remain Closed when Power ≥ 5.35 sec
Closed if connected in test Period
≥ 5.35sec
G315
Normally open contacts of RE81-1 Remain Closed
Period ≥ 5.35sec
G316
Coil of RE81 Remains energized
NO contacts of RE81-1 fail Closed
C3RE81-1
G319
G302
G301
G306
G305
G309
G307
G308
G108
Normally open contacts of RE81-2 remain Closed when Power ≥ 92 MW
Closed if connected when Power < 92 MW
EMF to circuit node common to pins 88 of contacts of RE84-1
EMF to circuit node common to pins 88 of contacts of RE84-2
EMF to circuit node common to pins 88 of contacts of RE81-2
EMF to pin 85 of RE81-2 pins NO contacts of RE80-2
(1a) Wire connection faults result in EMF to pin 85 of RE81-2
(1a) Wire connection faults result in EMF to pin 85 of RE84-1
(1a) Wire connection faults result in EMF to pin 85 of RE84-2
Closed as Expected when Period
Closed as Expected when Power < 92 MW
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G311
G312
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G314
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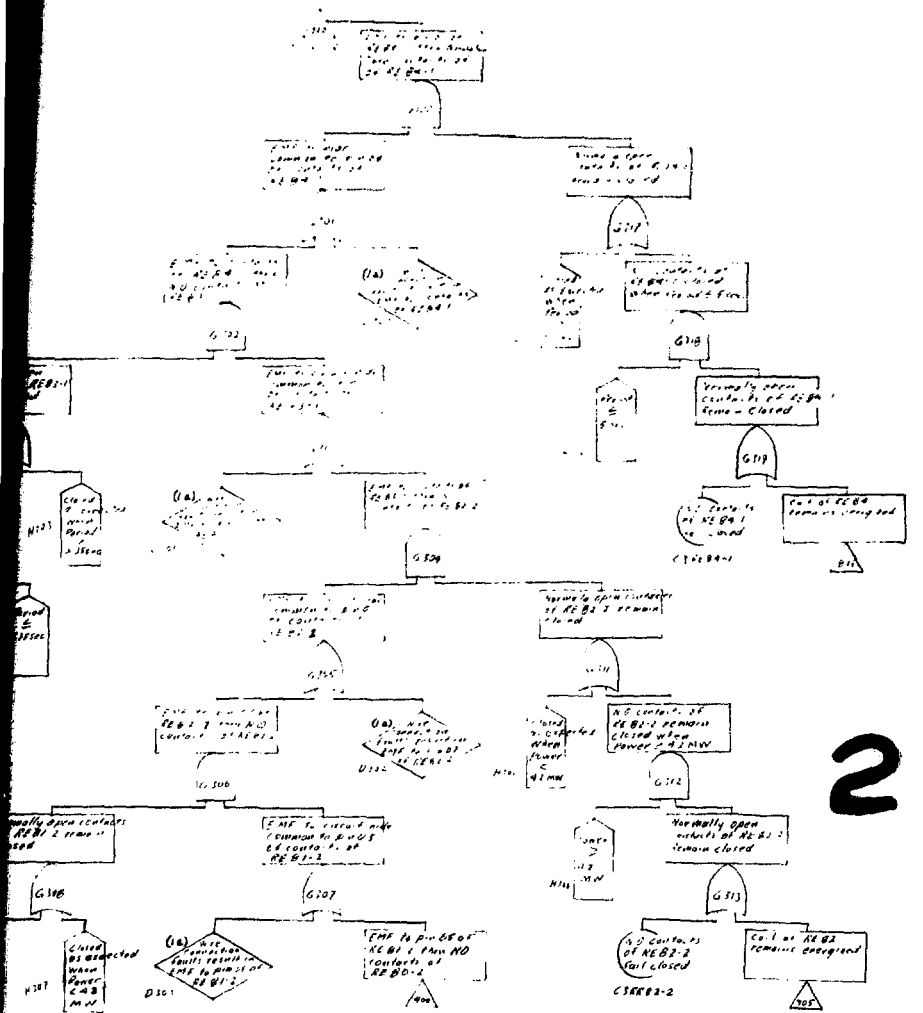
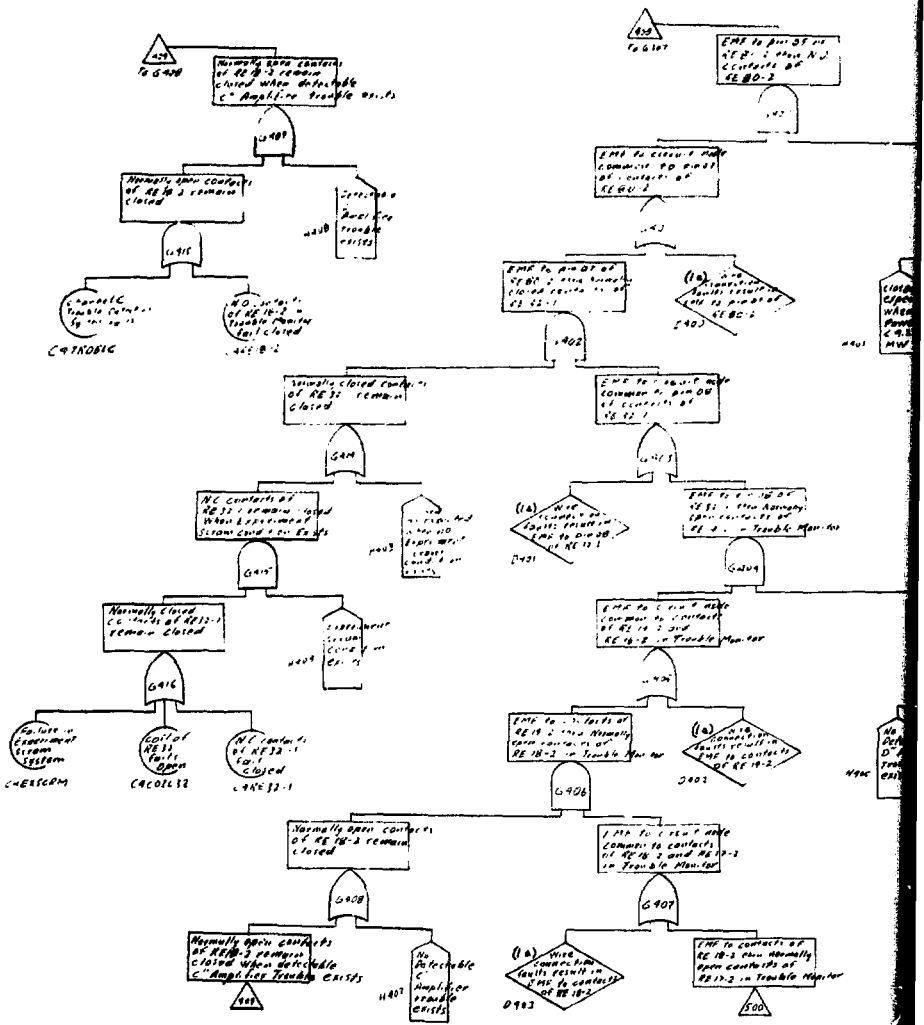
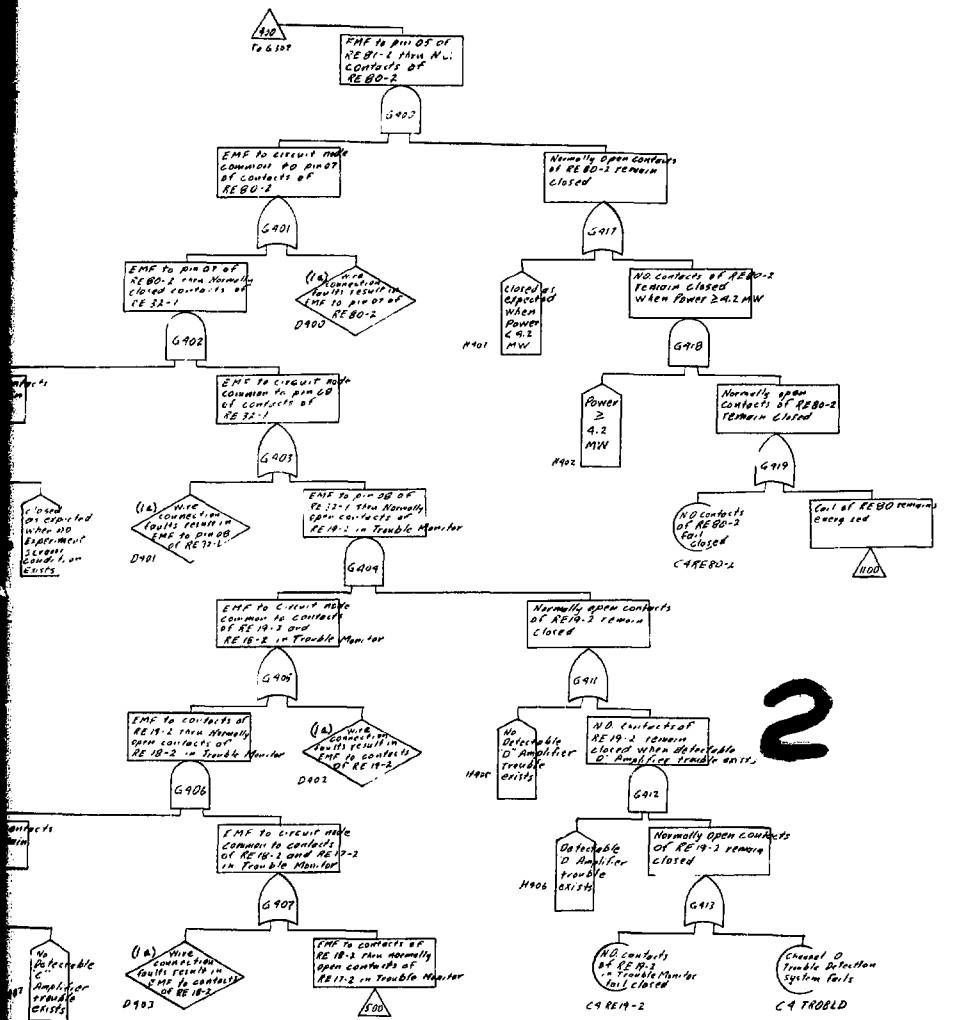


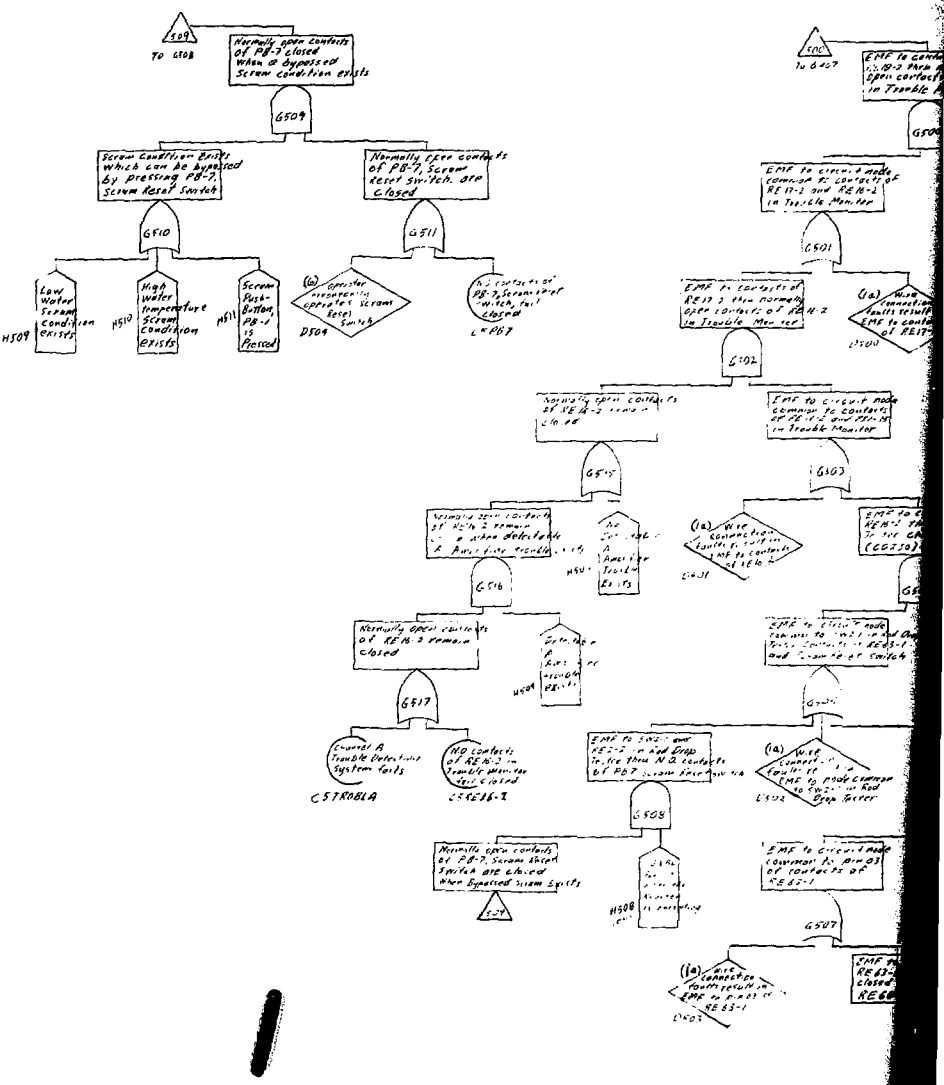
Fault tree for LPTR scram system (sheet 3).

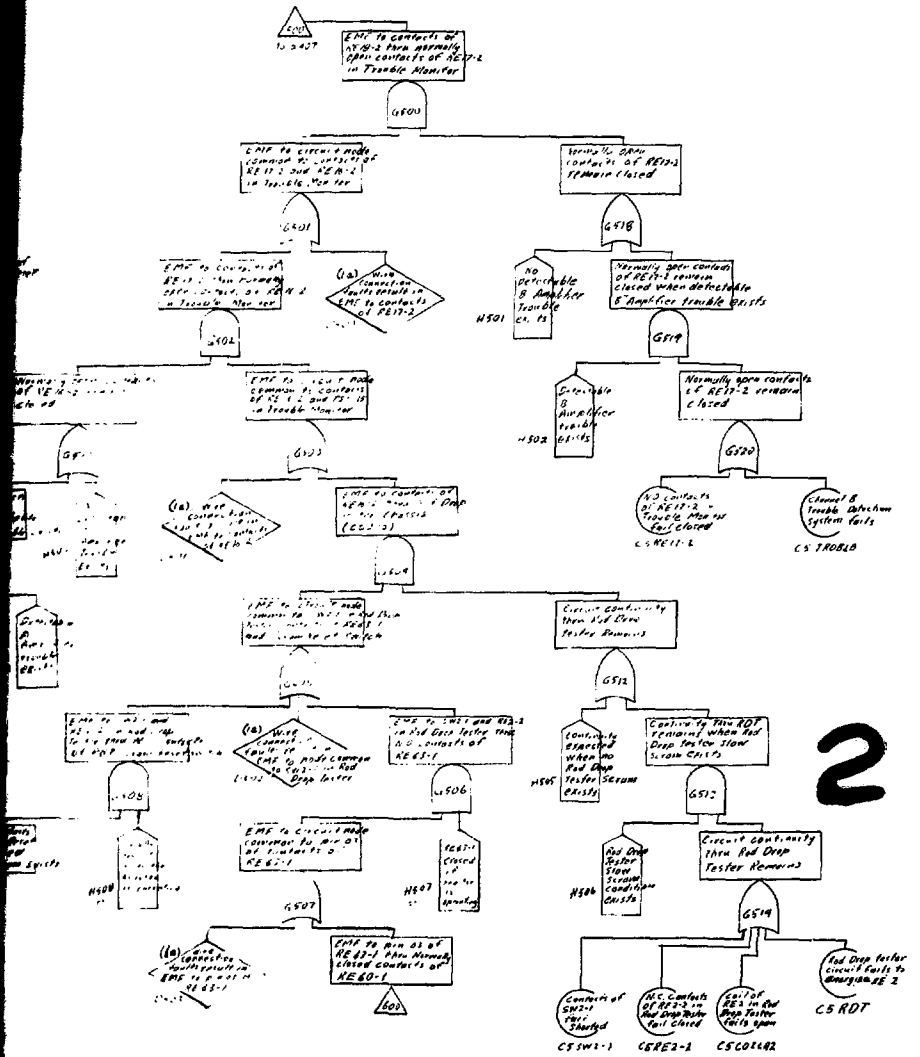


Fault tree for LPTR



Fault tree for LPTR scram system (sheet 4).


TO G508
Normally open contacts of PB-7 closed when a bypassed Scram condition exists
G509
Scram Condition Exists which can be bypassed by pressing PB-7, Scram Reset Switch
Normally open contacts of PB-7, Scram Reset Switch are closed
G510
G511
Low Water Scram Condition Exists
HS09
High Water Temperature Scram Condition Exists
HS10
Scram Push-Button, PB-1 is Pressed
HS11
(a) Operator momentarily operates Scram Reset Switch
DS04
One contacts of PB-7, Scram Reset Switch, are Closed
C=PB7
TO G507
EMF to circuit node common to contacts of RE13-2 and RE14-2 in Trouble Monitor
G501
EMF to contacts of RE13-2 thru normally open contacts of RE14-2 in Trouble Monitor
G502
(1a) Wire connection fault to coil EMF to contacts of RE13-2
C5001
Normally open contacts of RE14-2 remain open after a short detectable by Annunciator Trouble
G515
G503
HS01
(1a) Wire connection fault to coil EMF to contacts of RE16-1
C5031
Normally open contacts of RE14-2 remain closed
G516
Normally open contacts of RE16-2 remain closed
G517
HS09
Control A Trouble Detection System fails
C5TROBLA
HS contacts of RE16-2 in Trouble Monitor are closed
C5RE16-2
EMF to circuit node common to one of RE22-2 or one of RE23-2 and EMF to one thru NO contacts of PB7 Scram Reset Switch
G508
(1a) Wire connection fault to coil EMF to node common to one of RE22-2 or one of RE23-2
C5032
Normally open contacts of PB-7, Scram Reset Switch are closed when Bypassed Scram Exists
S29
HS08
EMF to circuit node common to contacts of RE83-1
G507
(1a) Wire connection fault to coil EMF to contacts of RE83-1
C5033



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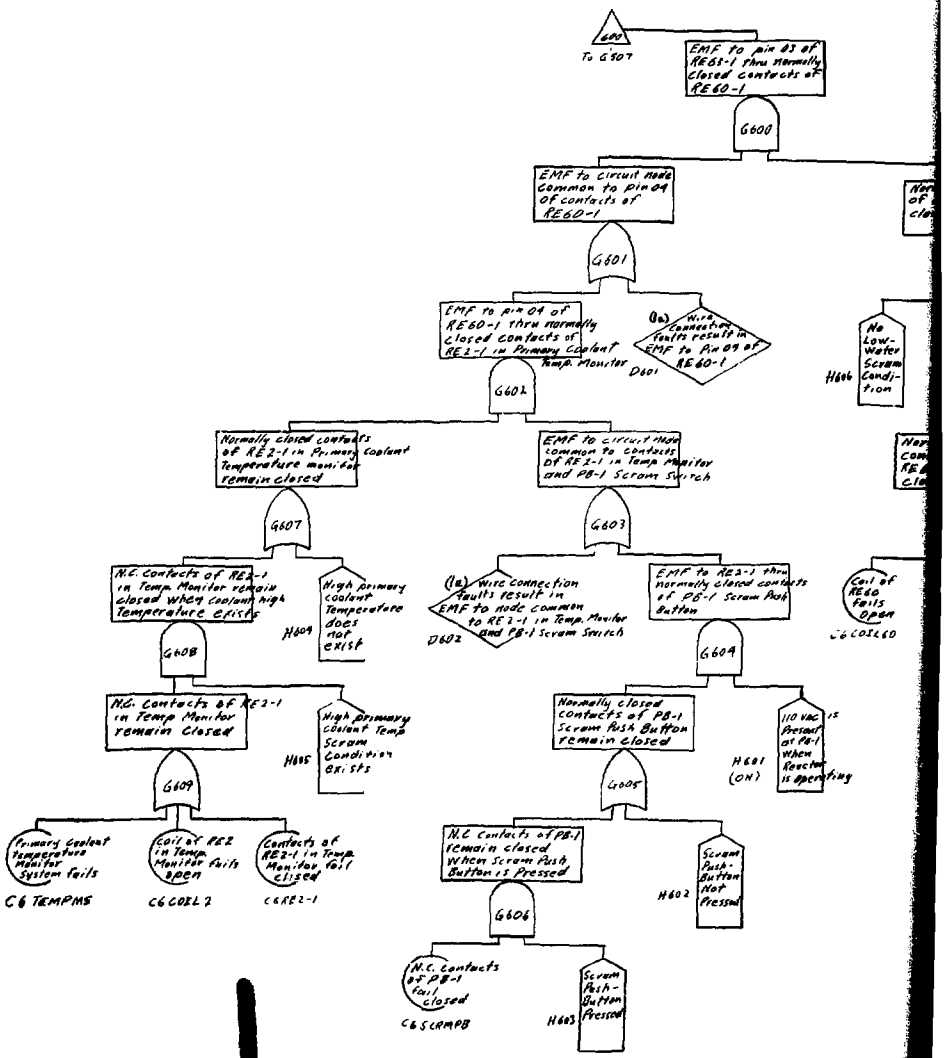
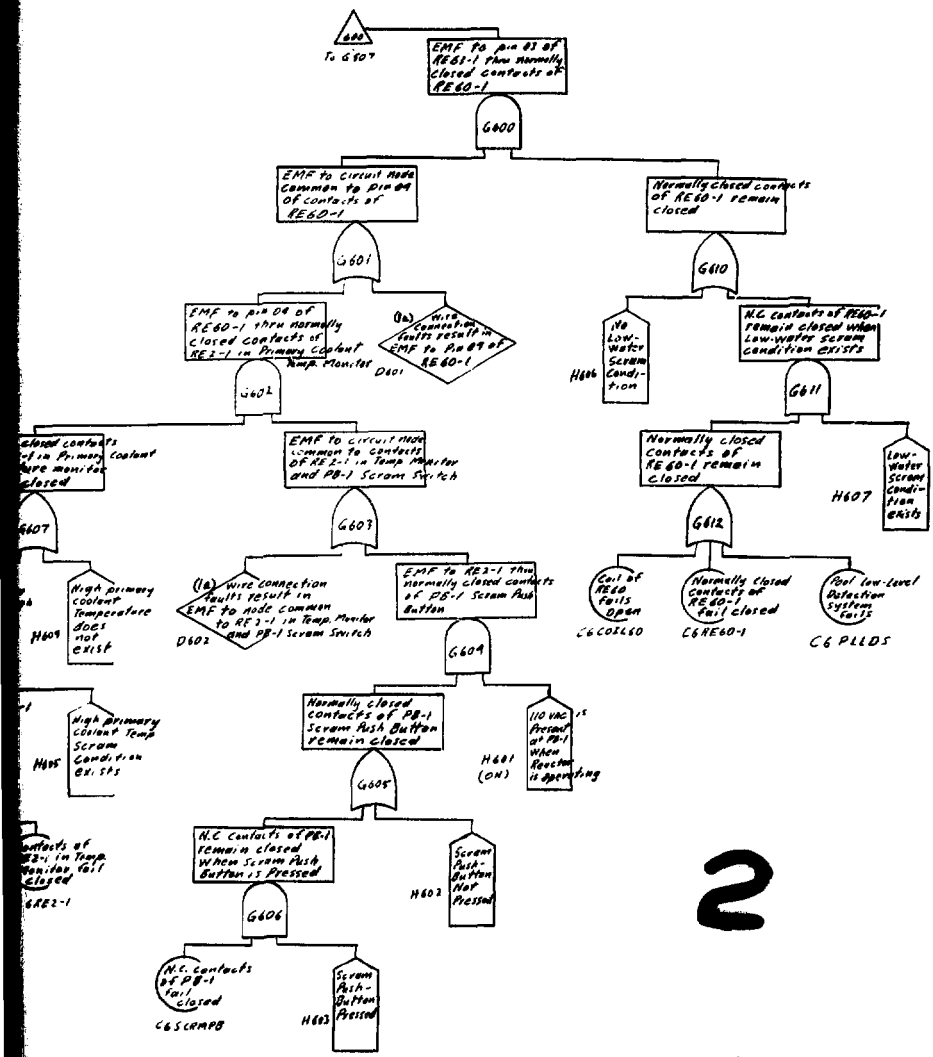
Fault tree for LPTR scram system (sheet 5).



Fault tree for LPTR scram system



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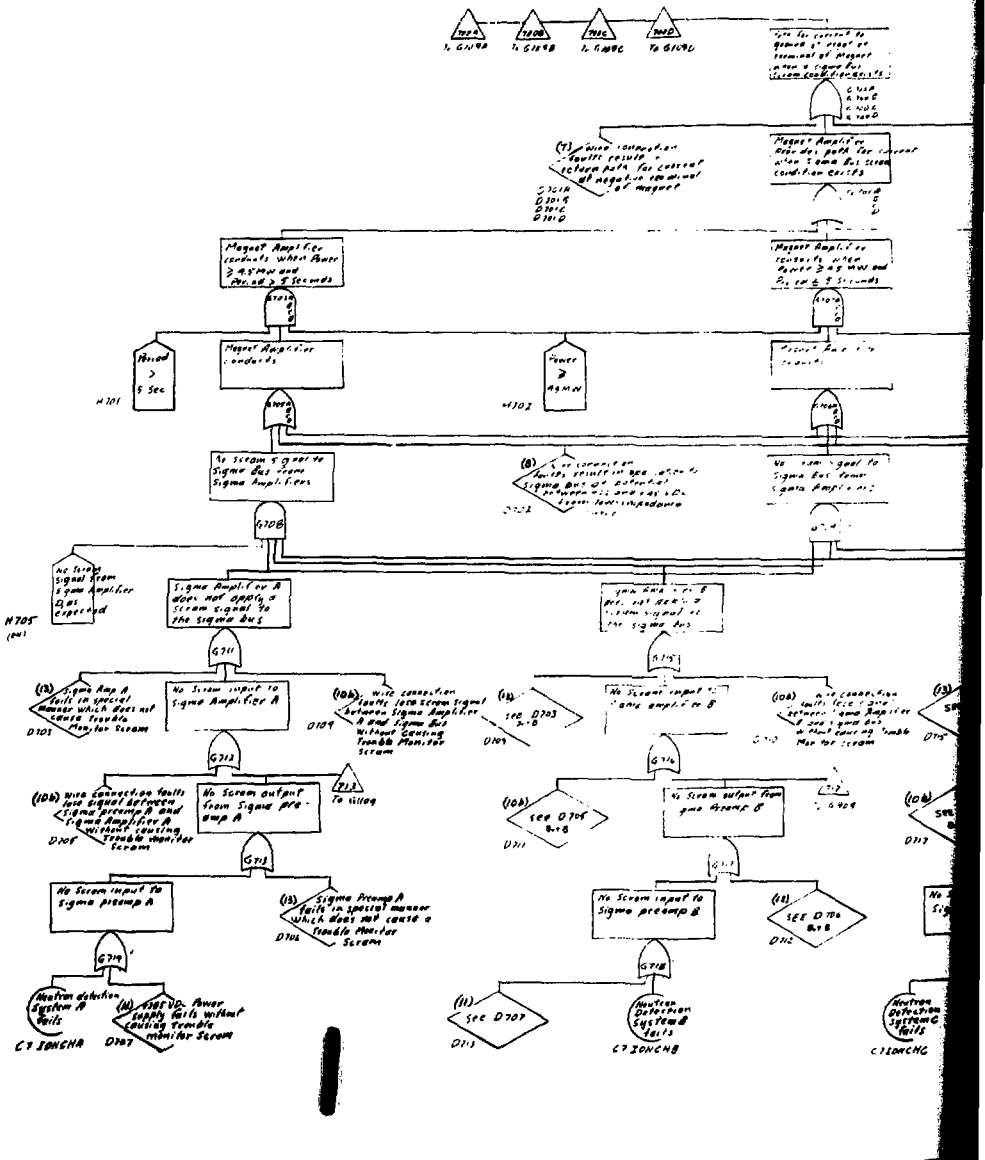
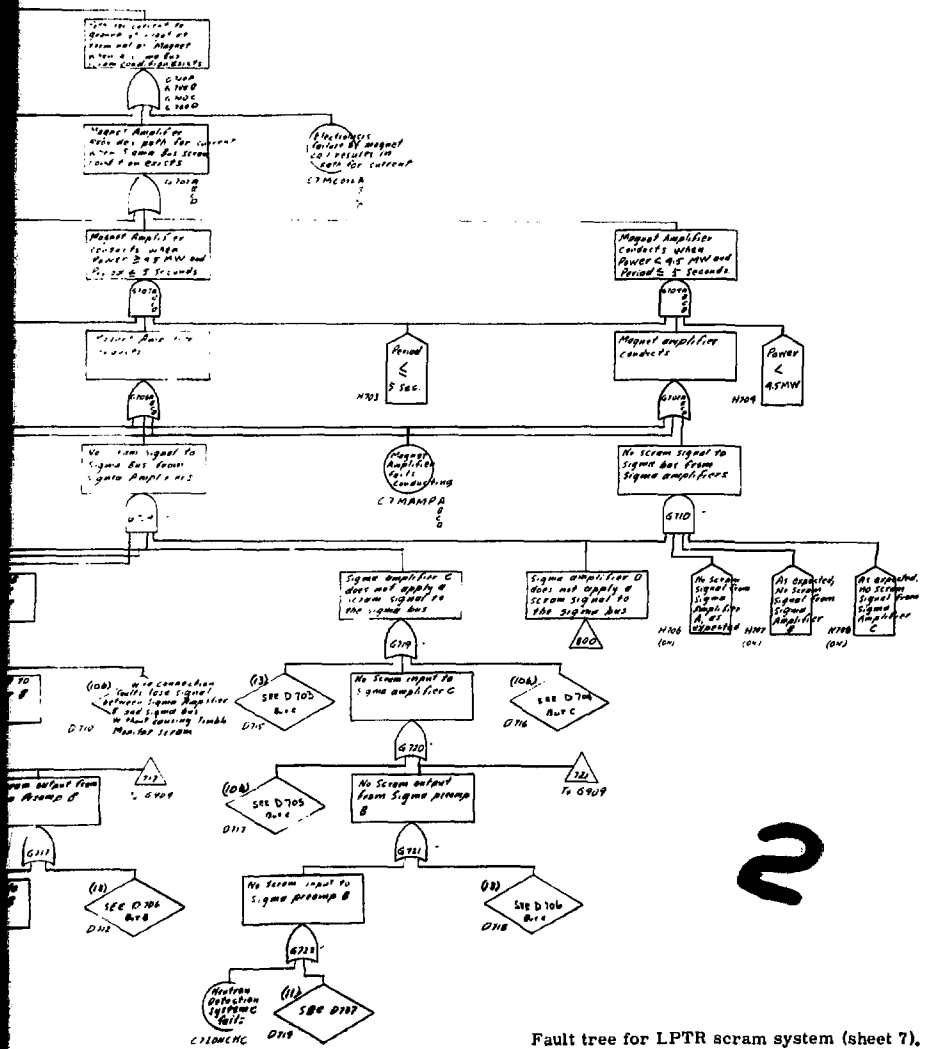
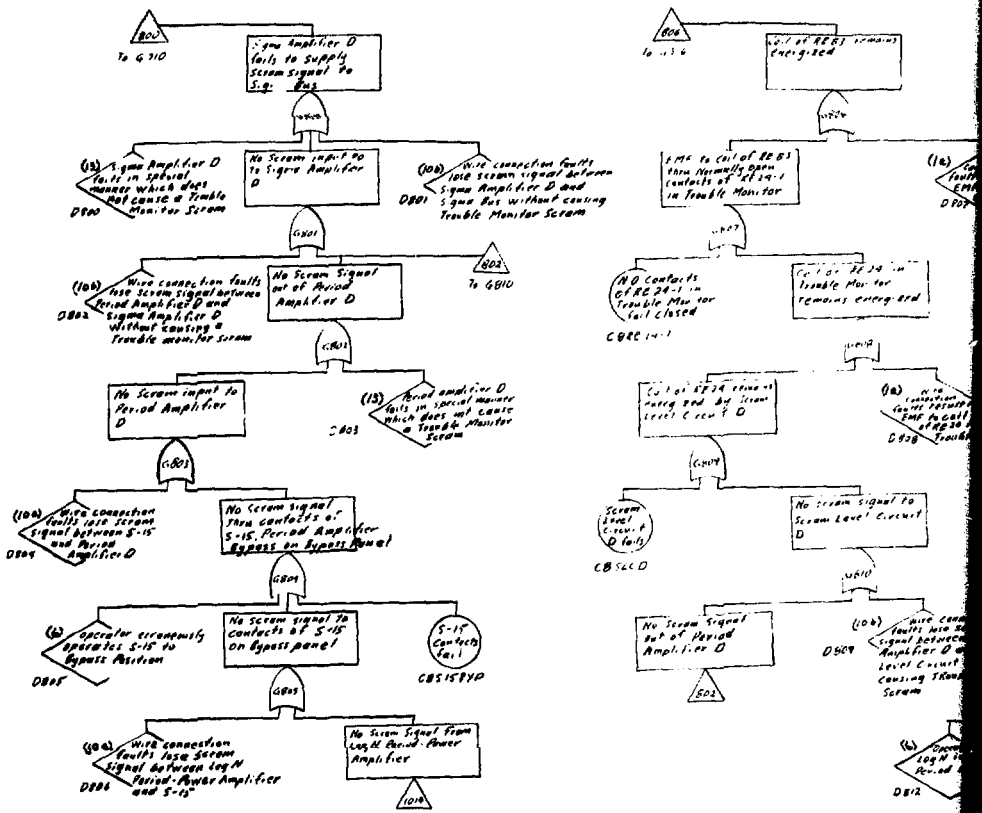
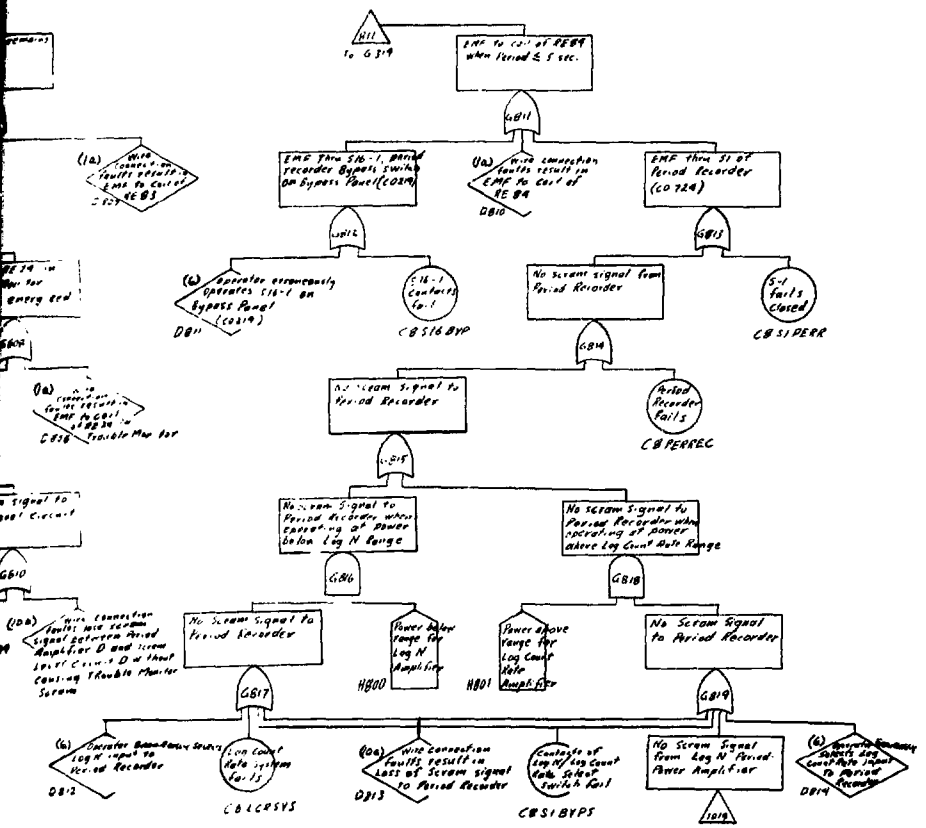
Fault tree for LPTR scram system (sheet 6).


To G1490
To G1498
To G1496
To G1494
Magnet Amplifier conducts when Power ≥ 4.5 MW and Period ≥ 5 Seconds
Period > 5 Sec
H701
Magnet Amplifier conducts
Power ≥ 4.5 MW
H702
No Scram Signal to Sigma Bus from Sigma Amplifiers
No Scram Signal from Sigma Amplifier does expected
H705
Sigma Amplifier A does not apply a Scram signal to the Sigma Bus
No Scram input to Sigma Amplifier A
No Scram output from Sigma pre-amp A
No Scram input to Sigma preamp A
Neutron detection System A fails
C7 ION CHA
No Scram input to Sigma preamp B
Neutron detection System B fails
C7 ION CHB
Neutron detection System C fails
C7 ION CHC
To G1499
To G1498
To G1496
To G1494
Magnet Amplifier conducts when Power ≥ 4.5 MW and Period ≥ 5 Seconds
Magnet Amplifier conducts
Power ≥ 4.5 MW
No Scram Signal to Sigma Bus from Sigma Amplifiers
No Scram input to Sigma Amplifier B
No Scram output from Sigma preamp B
No Scram input to Sigma preamp B
SEE D706 B+B
D712
SEE D707
D713

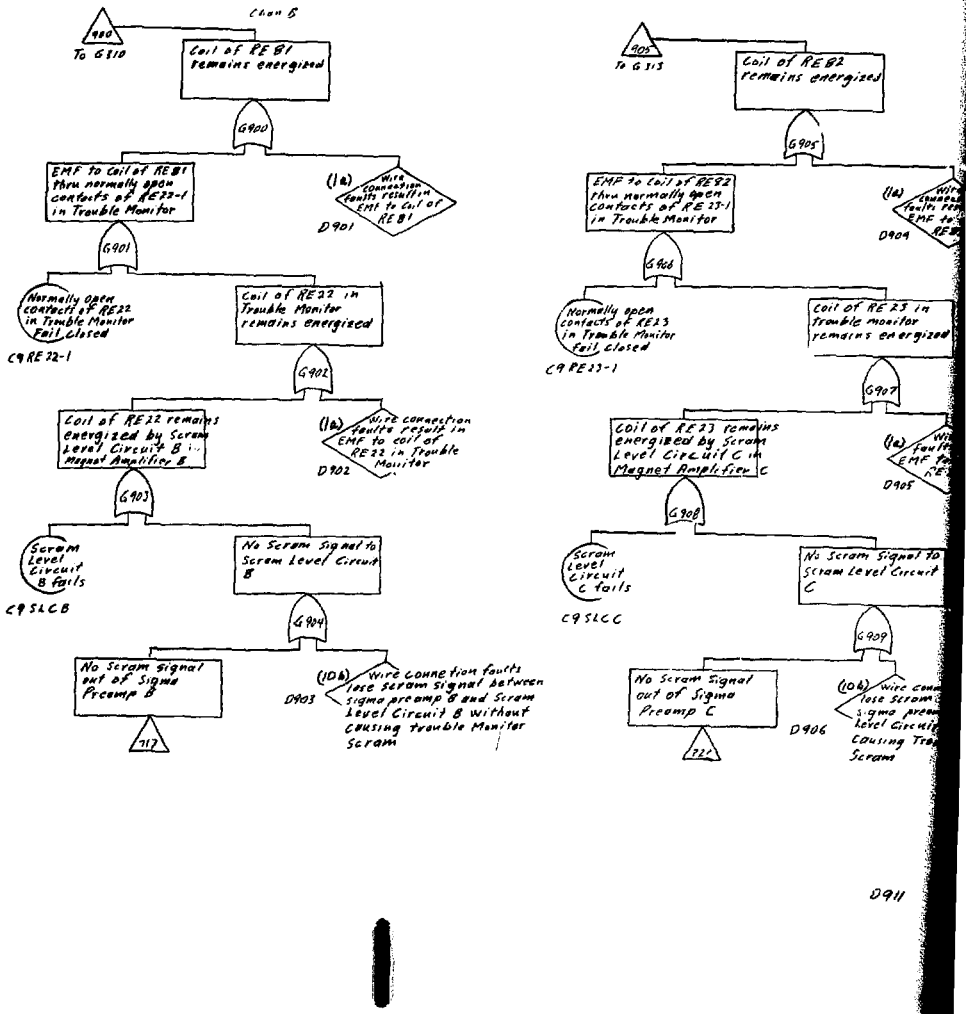


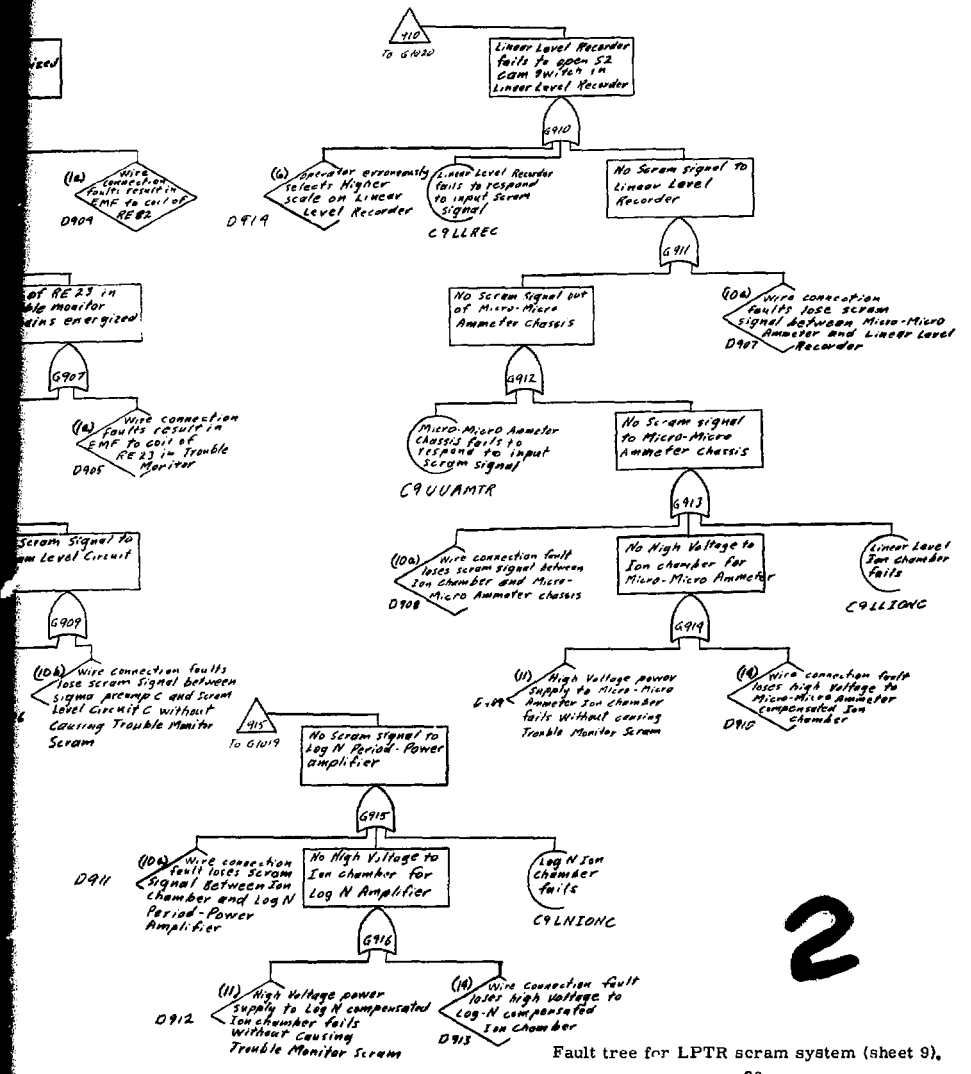
Fault tree for LPTR scram system (sheet 7).


To G310
Signa Amplifier D fails to Supply Scram Signal To Sig. Bus
G502
(13) Signa Amplifier D fails in special manner which does not cause a Trouble Monitor Scram
D800
No Scram input to Signa Amplifier D
(10b) Wire connection faults lose scram signal between Signa Amplifier D and Signa Bus without causing Trouble Monitor Scram
D801
(10a) Wire connection faults lose Scram signal between Period Amplifier D and Signa Amplifier D without causing a Trouble monitor scram
D802
No Scram Signal out of Period Amplifier D
G501
To G810
No Scram input to Period Amplifier D
G503
(13) Period amplifier D fails in special manner which does not cause a Trouble Monitor Scram
D803
(10a) Wire connection faults lose scram signal between S-15 and Period Amplifier D
D804
No Scram Signal thru contacts of S-15, Period Amplifier Bypass on Bypass Panel
G504
(c) Operator erroneously operates S-15 to Bypass Position
D805
No Scram signal to contacts of S-15 on Bypass panel
S-15 Contacts Fail
CBS15BYPD
G505
(10a) Wire connection faults lose Scram signal between Log N Period-Power Amplifier and S-15
D806
No Scram Signal From Log N Period-Power Amplifier
1019
To G316
Coil of RE83 remains Energized
G506
EMF to coil of RE83 thru Normally open contacts of RT19-1 in Trouble Monitor
G507
(12) Trouble Monitor EMF
D807
NO Contacts of RE 29-1 in Trouble Monitor fail closed
CBRE19-1
Coil of RE 29 in Trouble Monitor remains energized
G508
Coil of RE34 remains energ and Scram Level Circuit D
G509
(12) Trouble Monitor EMF to coil of RE34 Trouble
D808
Scram Level Circuit D fails
CBSLCD
No Scram Signal to Scram Level Circuit D
G510
No Scram Signal out of Period Amplifier D
502
(10a) Wire connection faults lose Scram signal between Amplifier D and Level Circuit D causing Trouble Scram
D809
(c) Operator Log N Period
D812

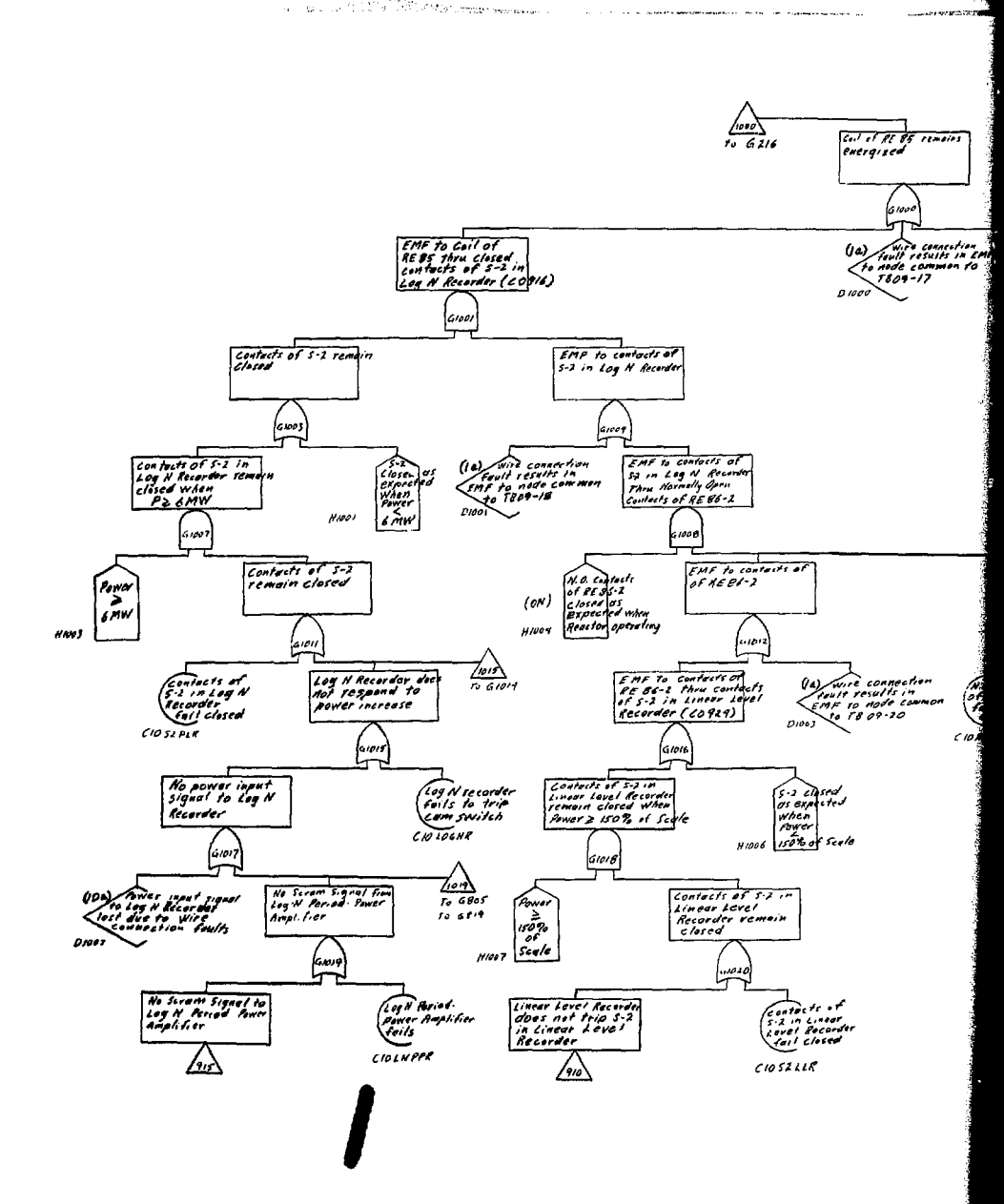


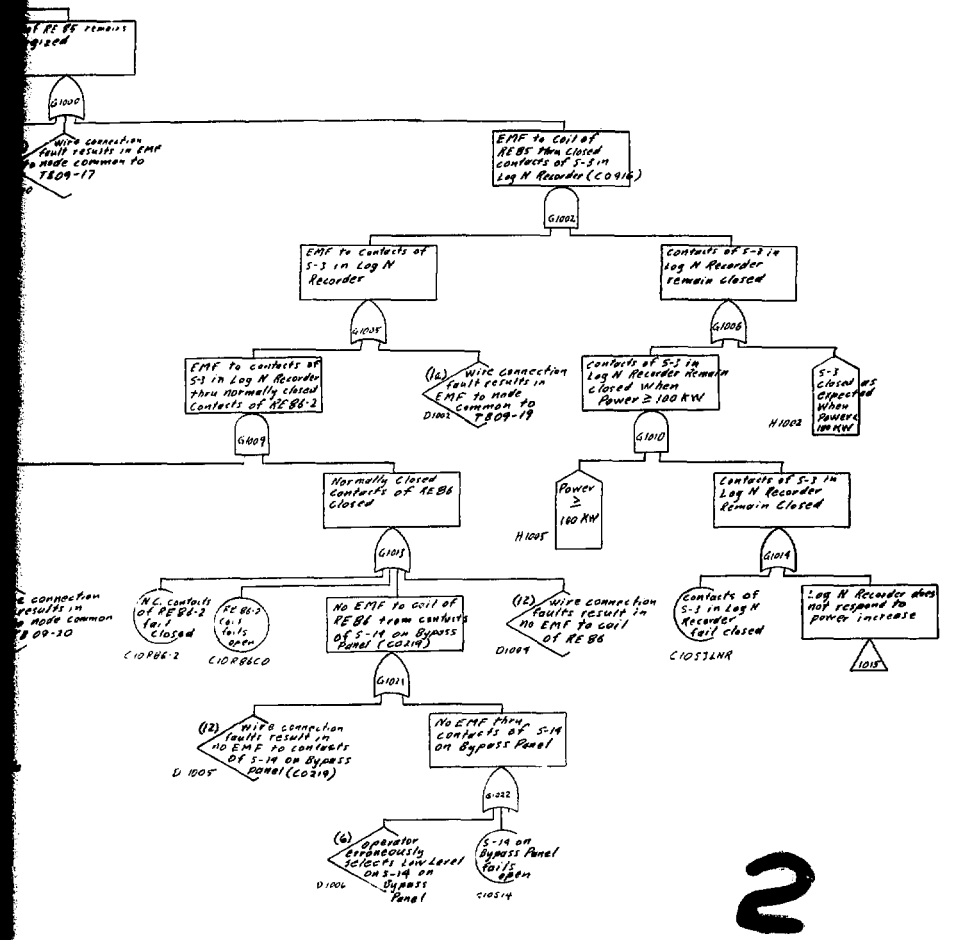
Fault tree for LPTR scram system (sheet 8).


Chan B
900
To G 810
Coil of RE 81 remains energized
G900
EMF to coil of RE 81 thru normally open contacts of RE 22-1 in Trouble Monitor
(1a) Wire connection faults result in EMF to coil of RE 81
D 901
G901
Normally open contacts of RE 22 in Trouble Monitor Fail Closed
C9 RE 22-1
Coil of RE 22 in Trouble Monitor remains energized
G902
Coil of RE 22 remains energized by Scram Level Circuit B in Magnet Amplifier B
(1a) Wire connection faults result in EMF to coil of RE 22 in Trouble Monitor
D 902
G903
Scram Level Circuit B fails
C9 SLCB
No Scram Signal to Scram Level Circuit B
G904
No Scram signal out of Sigma Preamp B
717
(10b) Wire connection faults lose Scram Signal between sigma preamp B and Scram Level Circuit B without causing Trouble Monitor Scram
D903
905
To G 813
Coil of RE 82 remains energized
G905
EMF to Coil of RE 82 thru normally open contacts of RE 23-1 in Trouble Monitor
(1a) Wire
D904
G906
Normally open contacts of RE 23 in Trouble Monitor Fail closed
C9 RE 23-1
Coil of RE 23 in Trouble monitor remains energized
G907
Coil of RE 23 remains energized by Scram Level Circuit C in Magnet Amplifier C
(1a) Wi
D905
G908
Scram Level Circuit C fails
C9 SLCC
No Scram Signal to Scram Level Circuit C
G909
No Scram Signal out of Sigma Preamp C
722
(10b) Wire con
D906
D911

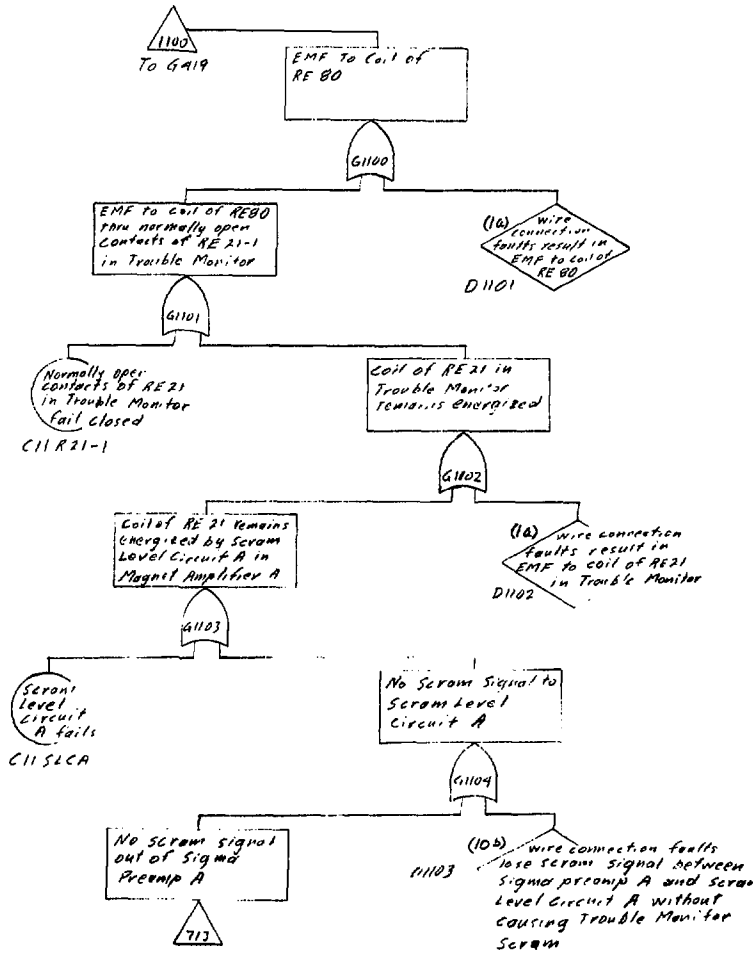


Fault tree for LPTR scram system (sheet 9).


1000
To G216
Coil of RE 85 remains energized
G1000
EMF to Coil of RE 85 thru closed contacts of S-2 in Log N Recorder (C0916)
(1a) Wire connection fault results in EMF to node common to T809-17
D1000
G1001
Contacts of S-2 remain closed
EMF to contacts of S-2 in Log N Recorder
G1003
G1009
Contacts of S-2 in Log N Recorder remain closed when P ≥ 6MW
S-2 closes as expected when Power ≥ 6MW
H1001
(1a) Wire connection fault results in EMF to node common to T809-18
D1001
EMF to contacts of S2 in Log N Recorder Thru Normally Open Contacts of RE86-2
G1007
G1008
Power ≥ 6MW
H1003
Contacts of S-2 remain closed
N.O. Contacts of RE85-2 closed as expected when Reactor operating
(ON)
H1004
EMF to contacts of of RE81-2
G1011
G1012
1015
To G1019
Contacts of S-2 in Log N Recorder fail closed
C10S2PLR
Log N Recorder does not respond to power increase
EMF to contacts of RE 86-2 thru contacts of S-2 in Linear Level Recorder (C0929)
(1a) Wire connection fault results in EMF to node common to T809-20
D1003
G1015
G1016
No power input signal to Log N Recorder
Log N recorder fails to trip cam switch
C10LOGNR
Contacts of S-2 in Linear Level Recorder remain closed when Power ≥ 150% of Scale
S-2 closed as expected when Power ≥ 150% of Scale
H1006
G1017
G1018
(2D) Power input signal to Log N Recorder lost due to wire connection faults
D1007
No Scram Signal from Log N Period-Power Amplifier
1019
To G805
To G819
Power ≥ 150% of Scale
H1007
Contacts of S-2 in Linear Level Recorder remain closed
G1019
G1020
No Scram Signal to Log N Period Power Amplifier
915
Log N Period-Power Amplifier fails
C10LNPPR
Linear Level Recorder does not trip S-2 in Linear Level Recorder
910
Contacts of S-2 in Linear Level Recorder fail closed
C10S2LLR



Fault tree for LPTR scram system (sheet 10).



Fault tree for LPTR scram system (sheet 11).

1. a. A wiring or connection fault is assumed which places an unwanted emf at a particular point in the circuit as described in the diamond. The undesired emf causes a circuit response which prevents a scram operation from occurring. The emf can be ac or dc at any level sufficient to produce the undesired result.

b. In this case, the undesired emf must be ac applied at any point to the node common to terminal 1 of transformer T-2 in any one of the four safety amplifiers, all the way to pins 03 and 05 of relay 62. Such a fault energizes all four magnet power supplies and prevents the shim rods from dropping via the slow scram system.

2. This diamond (D-100) was included for two reasons. The first reason is to provide a test for those computer runs in which without D-100 there would have been no minimal cut sets. (A cut set is a collection of one or more events which will cause the top event to occur.) Every computer run will have at least one cut set involving a single failure (D-100), thus providing a degree of assurance that the computer run was properly executed. The second reason for including D-100 is to give consideration to any common mode failure which might result in three or more shim rods failing to enter the core after all four had been released from the supporting magnets. The event represented by D-100 is considered to be an incredible event. It seems unlikely that even an earthquake could deform or tilt the core sufficiently to cause the rods to bind and fail to insert fully. Core melt is not a credible mechanism, as is shown by the analyses in chapter 15.2.1 in Ref. 1.

3. This fault can be caused by any mechanical failure or obstruction which would prevent an individual shim rod from dropping into the core.

4. This fault requires that an extremely unlikely combination of wire connection faults occur simultaneously so as to place an emf at the V7 and V8 terminals of the magnets and a current sink at the B^+ terminals, which is the opposite of the normal connections. It is included for completeness, but is considered to be incredible.

5. The magnets will hold the shim rods in place with either ac or dc current flowing (dc is normal). This fault requires a wire connection fault that places at the magnet B^+ terminals an ac or dc emf that provides sufficient current to energize the magnet and not burn it open.

6. This fault is caused by an operator deliberately but erroneously actuating the device described in the diamond. This either places the circuits in a state which prevents them from responding as they should to cause a scram, or else alters or bypasses the equipment or circuitry in a manner which prevents a scram.

7. Shim rod drop is normally caused by cutting off the magnet current at a point downstream from the negative terminal. The fault described in this diamond provides an unwanted alternate return path which bypasses the normal switching circuit and therefore allows magnet current to flow during a scram condition when it is not supposed to flow.

8. This fault represents a wiring connection fault that results in the shorting of the sigma bus to a low impedance source of emf in the range between +22 and +45 V dc. No such low-impedance source of emf within this range exists in the vicinity of the sigma bus or the sigma amplifiers. (A short to ground or dc voltage greater than +45 V results in a scram.) An open circuit between the sigma bus and magnet amplifier results in the cutoff of that magnet amplifier. A short to a voltage divider resulting in the required +22 to +45 V would be driven out of range by the cathode-follower output of the sigma amplifiers. The event represented by diamond 702 is considered to be incredible, but is included for completeness.

9. This failure would require coincident events to occur along with the power supply failure since the proper power-supply voltage level is monitored by a trouble monitor relay. This event might be a wiring connection fault or a relay fault. It is credible but unlikely.

10. a. Loss of signal or voltage can be caused by open- or short-circuit wiring connection faults which prevent the equipment being fed from detecting that a scram condition exists.

b. If such a loss of scram signal would normally initiate a trouble-monitor slow scram, the coincident wiring connection or relay faults must also exist which would prevent the trouble monitor scram from occurring. This is credible but unlikely.

11. A failure of the HV supply to the ion chambers prevents them from detecting a scram condition, and the power supply low-voltage monitor normally initiates a slow scram. This fault, therefore, requires a coincident wire connection or relay failure in the monitoring circuit, such that the expected trouble-monitor scram does not occur. This is considered credible but unlikely.

12. This fault is a wire connection open- or short-circuit fault which prevents the normal emf required for circuit operation from reaching the relay coil.

13. The composite safety amplifiers are normally monitored for proper operation by relays in the composite amplifier or by the input signal getting out of normal operating range, either of which would trip the slow scram or trouble-monitor scram circuits. This failure, therefore, requires the coincident failure of the trouble-monitor circuits by wiring-connection or relay faults which prevent trouble-monitor scram from occurring. This is credible but unlikely.

14. Any wire connection short or open circuit in the ion chamber's HV power supply leads will inhibit ion chamber operation, and so prevent it from transmitting a scram level signal.

Appendix C. Results of Computer Analysis of Fault Tree

Table C-1 lists the 17 computer runs made on the fault tree considered in this study and summarizes the results of each run. Computer printouts of the cut sets for the 17 runs are reproduced at the end of this appendix.

Table C-1. Summary of the computer runs made in the fault tree analysis of the LPTR scram system. The top event is defined as three or more shim rods failing to fully enter the core when a scram condition exists.

Computer run	Assumption	Number of single faults producing top event	Number of double faults producing top event
1	Power >4.5 MW, period 1 sec (tests sigma bus scram functions and power and slow scrams)	1 (D-100)	5
2	Same as run 1, except that log N channel is assumed failed or bypassed initially	1 (D-100)	5
3	Power >6 MW	1 (D-100)	5
4	Power >4.5 MW, reached gradually	1 (D-100)	8
5	Fast period (<1 sec) during startup, while in low power range (< 10 kW)	1 (D-100)	184
6	Same as run 5 except for higher power range (>100 kW)	6 (D-100, -812, -811, -913, C9LNIONC, C10LNPPR)	99
7	Low-primary-coolant-flow scram condition	9	None
8	Experiment scram condition	15	None
9	Low-primary-coolant-level scram condition	24	None
10	High-primary-coolant-temperature scram condition	25	None
11	Actuation of manual scram push button	24	None
12	Power exceeds three-fourths of full scale (linear)	27	None
13	Same as run 12, plus fast period (<1 sec)	1 (D-100)	None
14	Same as run 13 except reactor in high power range	1 (D-100)	None
15	Failure of slow scram and fast period scram, resulting from failure to turn on these scram gates	2 (D-100, -702)	None
16	Same as run 15, but resulting from failed components	2 (D-100, -702)	None
17	Same as run 15, but testing for triple failures	2 (D-100, -702)	None (716 triples)

The computer runs of greatest significance to this study are runs 15, 16, and 17. Run 16 represents the specified startup accident. Initial conditions for the computer data deck (see Table 2) represent the failure of the slow scram chain (D-200) and the fast period channel (log N ion chamber failed). Under these conditions, the reactor is scrammed by any one of the three power-level channels through the sigma bus and magnet amplifiers. The computer run results in two single failures which can cause a failure to scram. These are represented by diamonds D-100 and D-702. The diamond notes 2 and 8 (Appendix B) explain why these events are unlikely.

Computer run 15 also simulates the specified startup accident by a different method, but with results identical to run 16. Instead of failing components in the fault tree as was done in run 16, in run 15 the gates which enable the slow scram chain and the fast period scram are not turned on. This simulates failure of the slow scram mechanism (in which B^+ voltage is removed from the magnet coils) and the fast-period scram channel.

Computer run 17 uses the same rates (failure data) input as used in run 15, but tests for combinations of triple failures. The run reveals a total of 716 combinations of triple failures which will result in failure to scram for the specified startup accident. (The specified startup accident postulates failure of the slow scram chain and fast period channel as initial conditions. These are in addition to the triple component failures.) The 716 combinations of triple failures consist of combinations, taken three at a time, of elements represented by circles and diamonds in the three redundant power-level scram channels A, B, and C. The bulky tabulation of these cut sets is not included in the report.

Computer run 1 and runs 3 through 14 represent normal scram conditions with no assumed initial failure.

Computer run 1 represents both high power ($\geq$4.5 MW) and fast period ($\leq$1 sec). This is a test of the sigma bus scram functions. In addition, the period and power slow scrams also are tested (power $\geq$4.2 MW and period $\leq$1.2 sec), since these conditions are included in the assumed initial conditions. For this scram condition, there are no credible single or double failures. The incredible failures which result from this run include D-100 as the only single, and D-702 in conjunction with a failure of the slow scram chain.

Computer run 2 is the same as run 1 except that the log N channel is assumed failed or bypassed initially. The results for run 2 are identical with the results for run 1. This shows that the reactor can operate safely and withstand a single failure even with the period scram channel bypassed or failed.

Computer run 3 assumes the power has exceeded the 200% (6-MW) level. This introduces one additional slow scram. This scram mechanism does not affect the failure analysis as far as single and double failures are concerned. The results are identical with those of computer runs 1 and 2.

Computer run 4 assumes the power has exceeded the 150% (4.5-MW) level gradually without generating a 20-sec-period rundown or a 1-sec-period scram. The cut sets for this run include all those for run 1, plus three additional double failures

involving diamond 702 in conjunction with components in the slow scram chain. The interpretation of this result is essentially the same as that for computer run 1, i.e., there are no credible single or double failures which will result in a failure to scram.

Computer run 5 assumes a fast period (≤1 sec) during startup, while in the low power range (<10 kW), i.e., before switching from the log-count-rate period amplifier to the log-N period amplifier. The run tests the ability of the system to withstand single and double failures and scram the reactor before power reaches the 150% level. (Run 1 covers the case of fast period on startup where power exceeds 150%.) There are no credible single failures which can result in failure to scram. There are 184 combinations of double failures (including six involving the incredible event represented by D-702) which could result in failure to scram before reactor power reaches the 150% level.

Computer run 6 assumes the same condition as run 5 except that the analysis is for the power range after the operator has switched from the log-count-rate period amplifier to the log-N period amplifier (power >100 kW). This run results in single failures in the log-N period/power amplifier channel which could result in failure to scram before power reaches the 150% level. Any single component in this channel which results in failure of the channel to function results in a failure to scram under these conditions. In run 15 this channel is assumed failed for the specified startup accident.

Computer runs 7 through 12 each test a scram function on the slow scram chain. These conditions are not sensed on the fast scram (sigma bus) circuitry. Therefore, in each case there are several single failures that result in failure of a particular scram condition to bring about a scram. These include failure of the contacts of relay 62 (RE-62) to open, shorts to ac voltage in the magnet power supply circuitry, shorts to ac power on the relay scram chain, and failure of the contacts of the relay for that particular scram function to open. In each case only a single failure is required as this is a single, series relay chain.

Computer run 7 assumes the low-primary-coolant-flow scram condition. This run results in nine cut sets representing single failures.

Computer run 8 assumes the experiment scram condition. This run results in 15 cut sets representing single failures.

Computer run 9 assumes the low-primary-coolant-level scram condition and results in 24 cut sets representing single failures.

Computer run 10 assumes the high-primary-coolant-temperature scram condition. This run results in 25 cut sets representing single failures.

Computer run 11 assumes the actuation of the manual scram push button. This run results in 24 cut sets representing single failures. There are several ways the operator can scram the reactor if the scram system should fail to respond to the manual scram push button. These are discussed in the operator's procedures for the LPTR.

Computer run 12 assumes that the power level exceeds the level represented by three-fourths of full scale on the linear level recorder. This function is sensed on the slow scram chain only. This run results in 27 cut sets representing single failures.

Computer run 13 assumes the same condition as in run 12, plus the assumption of a fast period (≤1 sec). The reactor power is in the low power range, i.e., the period recorder is still connected to the log-count-rate meter. This run results in no credible single or double failures which can prevent reactor scram. The diamond D-100 is in the only cut set found.

Computer run 14 is the same as run 13 except that the reactor is in the high power range, i.e., the period recorder has been switched to the log N channel. The results of this run are identical with those of run 13.

The cut sets for the 17 computer runs are reproduced on the following pages.

COMPUTER PRINTOUTS LISTING CUT SETS AND COMPONENTS FOUND IN CRITICAL PATHS

Runs 1, 2, 3

```
1
 MINIMAL CUT SETS FOUND BY COMBO FOR          LPTR FAULT TREE SAFETY ANALYSIS
CUT SET #   1  D100
CUT SET #   2  D202      D702
CUT SET #   3  D201      D702
CUT SET #   4  C2RE62-1  D702
CUT SET #   5  C2RE62-2  D702
CUT SET #   6  D200      D702

****** END OF CRITICAL PATHS ******



1
CRITICAL COMPS FOUND IN PATHS

D702      D202      D201      C2RE62-1  C2RE62-2  D200      D100
```

Run 4

```
1
 MINIMAL CUT SETS FOUND BY COMBO FOR          LPTR FAULT TREE SAFETY ANALYSIS
CUT SET #   1  D100
CUT SET #   2  D301      D702
CUT SET #   3  D300      D702
CUT SET #   4  D203      D702
CUT SET #   5  D202      D702
CUT SET #   6  D201      D702
CUT SET #   7  C2RE62-1  D702
CUT SET #   8  C2RE62-2  D702
CUT SET #   9  D200      D702

****** END OF CRITICAL PATHS ******



1
CRITICAL COMPS FOUND IN PATHS

D702      D301      D300      D203      D202      D201      C2RE62-1  C2RE62-2  D200      D100
```

Run 5

```
1
 MINIMAL CUT SETS FOUND BY COMBO FOR          LPTR FAULT TREE SAFETY ANALYSIS
CUT SET #   1  D100              CUT SET #  11  C8S16BYP D913
CUT SET #   2  C8LCRSYS D912     CUT SET #  12  D811      D912
CUT SET #   3  C8LCRSYS D913     CUT SET #  13  D811      D913
CUT SET #   4  C8S1BYPS D912     CUT SET #  14  C9LNIONC  C8LCRSYS
CUT SET #   5  C8S1BYPS D913     CUT SET #  15  C9LNIONC  C8S1BYPS
CUT SET #   6  D812      D912     CUT SET #  16  C9LNIONC  D812
CUT SET #   7  D812      D913     CUT SET #  17  C9LNIONC  D813
CUT SET #   8  D813      D912     CUT SET #  18  C9LNIONC  C8S16BYP
CUT SET #   9  D813      D913     CUT SET #  19  C9LNIONC  D811
CUT SET #  10  C8S16BYP D912     CUT SET #  20  D911      C8LCRSYS
```

Run 5 (Contd.)

```
CUT SET #  21  D911    C8S1BYPS
CUT SET #  22  D911    D812
CUT SET #  23  D911    D813
CUT SET #  24  D911    C8S16BYP
CUT SET #  25  D911    D811
CUT SET #  26  C10LNPPR C8LCRSYS
CUT SET #  27  C10LNPPR C8S1BYPS
CUT SET #  28  C10LNPPR D812
CUT SET #  29  C10LNPPR D813
CUT SET #  30  C10LNPPR C8S16BYP
CUT SET #  31  C10LNPPR D811
CUT SET #  32  C8PERREC D912
CUT SET #  33  C8PERREC D913
CUT SET #  34  C8PERREC C9LNIONC
CUT SET #  35  C8PERREC D911
CUT SET #  36  C8PERREC C10LNPPR
CUT SET #  37  C8S1PERR D912
CUT SET #  38  C8S1PERR D913
CUT SET #  39  C8S1PERR C9LNIONC
CUT SET #  40  C8S1PERR D911
CUT SET #  41  C8S1PERR C10LNPPR
CUT SET #  42  D810    D912
CUT SET #  43  D810    D913
CUT SET #  44  D810    C9LNIONC
CUT SET #  45  D910    D911
CUT SET #  46  D810    C10LNPPR
CUT SET #  47  D806    C8LCRSYS
CUT SET #  48  D806    C8S1BYPS
CUT SET #  49  D806    D812
CUT SET #  50  D806    D813
CUT SET #  51  D806    C8S16BYP
CUT SET #  52  D806    D811
CUT SET #  53  D806    C8PERREC
CUT SET #  54  D806    C8S1PERR
CUT SET #  55  D806    D810
CUT SET #  56  C8S15BYP C8LCRSYS
CUT SET #  57  C8S15BYP C8S1BYPS
CUT SET #  58  C8S15BYP D812
CUT SET #  59  C8S15BYP D813
CUT SET #  60  C8S15BYP C8S16BYP
CUT SET #  61  C8S15BYP D811
CUT SET #  62  C8S15BYP C8PERREC
CUT SET #  63  C8S15BYP C8S1PERR
CUT SET #  64  C8S15BYP D810
CUT SET #  65  D805    C8LCRSYS
CUT SET #  66  D805    C8S1BYPS
CUT SET #  67  D805    D812
CUT SET #  68  D805    D813
CUT SET #  69  D805    C8S16BYP
CUT SET #  70  D805    D811
CUT SET #  71  D805    C8PERREC
CUT SET #  72  D805    C8S1PERR
CUT SET #  73  D805    D810
CUT SET #  74  D804    C8LCRSYS
CUT SET #  75  D804    C8S1BYPS
CUT SET #  76  D804    D812
CUT SET #  77  D804    D813
CUT SET #  78  D804    C8S16BYP
CUT SET #  79  D804    D811
CUT SET #  80  D804    C8PERREC
CUT SET #  81  D804    C8S1PERR
CUT SET #  82  D804    D810
CUT SET #  83  D803    C8LCRSYS
CUT SET #  84  D803    C8S1BYPS
CUT SET #  85  D803    D812
CUT SET #  86  D803    D813
CUT SET #  87  D803    C8S16BYP
CUT SET #  88  D803    D811
CUT SET #  89  D803    C8PERREC
CUT SET #  90  D803    C8S1PERR
CUT SET #  91  D803    D810
CUT SET #  92  C3RE84-1 D912
CUT SET #  93  C3RE84-1 D913
CUT SET #  94  C3RE84-1 C9LNIONC
CUT SET #  95  C3RE84-1 D911
CUT SET #  96  C3RE84-1 C10LNPPR
CUT SET #  97  C3RE84-1 D806
CUT SET #  98  C3RE84-1 C8S15BYP
CUT SET #  99  C3RE84-1 D805

CUT SET # 100  C3RE84-1 D804
CUT SET # 101  C3RE84-1 D803
CUT SET # 102  D203    D912
CUT SET # 103  D203    D913
CUT SET # 104  D203    C9LNIONC
CUT SET # 105  D203    D911
CUT SET # 106  D203    D702
CUT SET # 107  D203    C10LNPPR
CUT SET # 108  D203    D806
CUT SET # 109  D203    C8S15BYP
CUT SET # 110  D203    D805
CUT SET # 111  D203    D804
CUT SET # 112  D203    D803
CUT SET # 113  D203    D802
CUT SET # 114  D203    D800
CUT SET # 115  D203    D801
CUT SET # 116  D202    D912
CUT SET # 117  D202    D913
CUT SET # 118  D202    C9LNIONC
CUT SET # 119  D202    D911
CUT SET # 120  D202    D702
CUT SET # 121  D202    C10LNPPR
CUT SET # 122  D202    D806
CUT SET # 123  D202    C8S15BYP
CUT SET # 124  D202    D805
CUT SET # 125  D202    D804
CUT SET # 126  D202    D803
CUT SET # 127  D202    D802
CUT SET # 128  D202    D800
CUT SET # 129  D202    D801
CUT SET # 130  D201    D912
CUT SET # 131  D201    D913
CUT SET # 132  D201    C9LNIONC
CUT SET # 133  D201    D911
CUT SET # 134  D201    D702
CUT SET # 135  D201    C10LNPPR
CUT SET # 136  D201    D806
CUT SET # 137  D201    C8S15BYP
CUT SET # 138  D201    D805
CUT SET # 139  D201    D804
CUT SET # 140  D201    D803
CUT SET # 141  D201    D802
CUT SET # 142  D201    D800
CUT SET # 143  D201    D801
CUT SET # 144  C2RE62-1 D912
CUT SET # 145  C2RE62-1 D913
CUT SET # 146  C2RE62-1 C9LNIONC
CUT SET # 147  C2RE62-1 D911
CUT SET # 148  C2RE62-1 D702
CUT SET # 149  C2RE62-1 C10LNPPR
CUT SET # 150  C2RE62-1 D806
CUT SET # 151  C2RE62-1 C8S15BYP
CUT SET # 152  C2RE62-1 D805
CUT SET # 153  C2RE62-1 D804
CUT SET # 154  C2RE62-1 D803
CUT SET # 155  C2RE62-1 D802
CUT SET # 156  C2RE62-1 D800
CUT SET # 157  C2RE62-1 D801
CUT SET # 158  C2RE62-2 D912
CUT SET # 159  C2RE62-2 D913
CUT SET # 160  C2RE62-2 C9LNIONC
CUT SET # 161  C2RE62-2 D911
CUT SET # 162  C2RE62-2 D702
CUT SET # 163  C2RE62-2 C10LNPPR
CUT SET # 164  C2RE62-2 D806
CUT SET # 165  C2RE62-2 C8S15BYP
CUT SET # 166  C2RE62-2 D805
CUT SET # 167  C2RE62-2 D804
CUT SET # 168  C2RE62-2 D803
CUT SET # 169  C2RE62-2 D802
CUT SET # 170  C2RE62-2 D800
CUT SET # 171  C2RE62-2 D801
CUT SET # 172  D200    D912
CUT SET # 173  D200    D913
CUT SET # 174  D200    C9LNIONC
CUT SET # 175  D200    D911
CUT SET # 176  D200    D702
CUT SET # 177  D200    C10LNPPR
```

Run 5 (Contd.)

CUT SET # 178	D200	D806	
CUT SET # 179	D200	C8S15BYP	
CUT SET # 180	D200	D805	
CUT SET # 181	D200	D804	
CUT SET # 182	D200	D803	
CUT SET # 183	D200	D802	
CUT SET # 184	D200	D800	
CUT SET # 185	D200	D801	

****** END OF CRITICAL PATHS ******

CRITICAL COMPS FOUND IN PATHS

D912	D913	C9LCRSYS
C8PERREC	C8S1PERR	D810
D203	D202	D201
C8S1BYPS	D812	D813
D906	C8S15BYP	D905
C2RE62-1	C2RE62-2	D200
C8S16BYP	D911	C9LNIONC
D804	D803	D802
D100	D100	C10LNPPR
D900	D901	C3RE84-1
D911		

Run 6

1

MINIMAL CUT SETS FOUND BY COMBO FOR LPTR FAULT TREE SAFETY ANALYSIS

~~CUT SET # 1~~	~~D912~~		
CUT SET # 2	D913		
CUT SET # 3	C9LNIONC		
CUT SET # 4	D911		
CUT SET # 5	C10LNPPR		
CUT SET # 6	D100		
CUT SET # 7	D806	D813	
CUT SET # 8	D806	C8S16BYP	
CUT SET # 9	D806	D811	
CUT SET # 10	D806	C8S1BYPS	
CUT SET # 11	D806	D814	
CUT SET # 12	D806	C8PERREC	
CUT SET # 13	D806	C8S1PERR	
CUT SET # 14	D306	D810	
CUT SET # 15	C8S15BYP	D913	
CUT SET # 16	C8S15BYP	C8S16BYP	
CUT SET # 17	C8S15BYP	D811	
CUT SET # 18	C8S15BYP	C8S1BYPS	
CUT SET # 19	C8S15BYP	D814	
CUT SET # 20	C8S15BYP	C8PERREC	
CUT SET # 21	C8S15BYP	C8S1PERR	
CUT SET # 22	C8S15BYP	D810	
CUT SET # 23	D805	D813	
CUT SET # 24	D805	C8S16BYP	
CUT SET # 25	D805	D811	
CUT SET # 26	D805	C8S1BYPS	
CUT SET # 27	D805	D814	
CUT SET # 28	D805	C8PERREC	
CUT SET # 29	D805	C8S1PERR	
CUT SET # 30	D805	D810	
CUT SET # 31	D804	D813	
CUT SET # 32	D804	C8S16BYP	
CUT SET # 33	D804	D811	
CUT SET # 34	D804	C8S1BYPS	
CUT SET # 35	D804	D814	
CUT SET # 36	D804	C8PERREC	
CUT SET # 37	D804	C8S1PERR	
CUT SET # 38	D804	D810	
CUT SET # 39	D803	D813	
CUT SET # 40	D803	C8S16BYP	
CUT SET # 41	D803	D811	
CUT SET # 42	D803	C8S1BYPS	
CUT SET # 43	D803	D814	
CUT SET # 44	D803	C8PERREC	
CUT SET # 45	D803	C8S1PERR	
CUT SET # 46	D803	D810	
CUT SET # 47	C3RE84-1	D804	
CUT SET # 48	C3RE84-1	C8S15BYP	
CUT SET # 49	C3RE84-1	D805	
CUT SET # 50	C3RE84-1	D904	
CUT SET # 51	C3RE84-1	D803	
~~CUT SET # 52~~	~~D903~~	~~D902~~	

CUT SET # 53	D203	D806	
CUT SET # 54	D203	C8S15BYP	
CUT SET # 55	D203	D805	
CUT SET # 56	D203	D804	
CUT SET # 57	D203	D803	
CUT SET # 58	D203	D802	
CUT SET # 59	D203	D800	
CUT SET # 60	D203	D801	
~~CUT SET # 61~~	~~D202~~	~~D902~~	
CUT SET # 62	D202	D806	
CUT SET # 63	D202	C8S15BYP	
CUT SET # 64	D202	D805	
CUT SET # 65	D202	D804	
CUT SET # 66	D202	D803	
CUT SET # 67	D202	D802	
CUT SET # 68	D202	D800	
CUT SET # 69	D202	D801	
~~CUT SET # 70~~	~~D201~~	~~D902~~	
CUT SET # 71	D201	D806	
CUT SET # 72	D201	C8S15BYP	
CUT SET # 73	D201	D805	
CUT SET # 74	D201	D804	
CUT SET # 75	D201	D803	
CUT SET # 76	D201	D802	
CUT SET # 77	D201	D800	
CUT SET # 78	D201	D801	
~~CUT SET # 79~~	~~C2RE62-1~~	~~D902~~	
CUT SET # 80	C2RE62-1	D806	
CUT SET # 81	C2RE62-1	C8S15BYP	
CUT SET # 82	C2RE62-1	D805	
CUT SET # 83	C2RE62-1	D804	
CUT SET # 84	C2RE62-1	D803	
CUT SET # 85	C2RE62-1	D802	
CUT SET # 86	C2RE62-1	D800	
CUT SET # 87	C2RE62-1	D801	
~~CUT SET # 88~~	~~C2RE62-2~~	~~D902~~	
CUT SET # 89	C2RE62-2	D806	
CUT SET # 90	C2RE62-2	C8S15BYP	
CUT SET # 91	C2RE62-2	D805	
CUT SET # 92	C2RE62-2	D804	
CUT SET # 93	C2RE62-2	D803	
CUT SET # 94	C2RE62-2	D802	
CUT SET # 95	C2RE62-2	D800	
CUT SET # 96	C2RE62-2	D801	
~~CUT SET # 97~~	~~D200~~	~~D902~~	
CUT SET # 98	D200	D806	
CUT SET # 99	D200	C8S15BYP	
CUT SET # 100	D200	D805	
CUT SET # 101	D200	D804	
CUT SET # 102	D200	D803	
CUT SET # 103	D200	D802	
CUT SET # 104	D200	D800	

Run 6 (Contd.)

```
CUT SET =  105  D200     D801                    D202     D201     C2RES2-1  C2RES2-2  D200
                                                 C9LNIDNC D911     D702      C19L4PPR  C9S19YPS
***** END OF CRITICAL PATHS *****                D804     D803     D802      D939      D931
                                                 D100     D914     C9PE22EC  C3PE84-1  D203

**********
CRITICAL COMPS FOUND IN PATHS

D912      D913      D813      C9S16BYP  D811
C2S1PERR  D910      D305      C9S15BYP  D905
```

Runs 15, 16

```
1
**********
 MINIMAL CUT SETS FOUND BY COMBO FOR          LPTR FAULT TREE SAFETY ANALYSIS
**********
CUT SET =   1  D702
CUT SET =   2  D100

***** END OF CRITICAL PATHS *****



1
**********
CRITICAL COMPONENTS FOUND IN PATHS

 D702      D100
```

INPUT DECKS SHOWING WHICH COMPONENTS AND HOUSES WERE TURNED ON

Run 1

/ RATES					
H101	0.0	0.0	H203	0.0	1.0
H202	0.0	0.0	H207	0.0	1.0
H205	0.0	1.0	H206	0.0	0.0
H301	0.0	0.0	H302	0.0	1.0
H303	0.0	0.0	H304	0.0	1.0
H305	0.0	0.0	H306	0.0	1.0
H307	0.0	0.0	H308	0.0	1.0
H401	0.0	0.0	H402	0.0	1.0
H403	0.0	1.0	H404	0.0	0.0
H405	0.0	1.0	H406	0.0	0.0
H407	0.0	1.0	H408	0.0	0.0
H501	0.0	1.0	H502	0.0	0.0
H503	0.0	1.0	H504	0.0	0.0
H505	0.0	1.0	H506	0.0	0.0
H509	0.0	0.0	H507	0.0	1.0
H510	0.0	0.0	H511	0.0	1.0
H602	0.0	1.0	H603	0.0	0.0
H604	0.0	1.0	H605	0.0	0.0
H606	0.0	1.0	H607	0.0	0.0
H701	0.0	0.0	H703	0.0	1.0
H702	0.0	1.0	H704	0.0	0.0
HA00	0.0	0.0	H801	0.0	1.0
H1001	0.0	1.0	H1003	0.0	0.0
H1002	0.0	0.0	H1005	0.0	1.0
H1006	0.0	0.0	H1007	0.0	1.0
H508	0.0	1.0	H601	0.0	1.0
H705	0.0	1.0	H706	0.0	1.0
H707	0.0	1.0	H708	0.0	1.0
H1004	0.0	1.0	[illegible]	[illegible]	[illegible]

END

Run 2

/ RATES					
H101	0.0	0.0	H203	0.0	1.0
H202	0.0	0.0	H207	0.0	1.0
H205	0.0	1.0	H206	0.0	0.0
H301	0.0	0.0	H302	0.0	1.0
H303	0.0	0.0	H304	0.0	1.0
H305	0.0	0.0	H306	0.0	1.0
H307	0.0	0.0	H308	0.0	1.0
H401	0.0	0.0	H402	0.0	1.0
H403	0.0	1.0	H404	0.0	0.0
H405	0.0	1.0	H406	0.0	0.0
H407	0.0	1.0	H408	0.0	0.0
H501	0.0	1.0	H502	0.0	0.0
H503	0.0	1.0	H504	0.0	0.0
H505	0.0	1.0	H506	0.0	0.0
H509	0.0	0.0	H507	0.0	1.0
H510	0.0	0.0	H511	0.0	1.0
H602	0.0	1.0	H603	0.0	0.0
H604	0.0	1.0	H605	0.0	0.0
H606	0.0	1.0	H607	0.0	0.0

Run 2 (Contd.)

H701	0.0	0.0	H703	0.0	1.0
H702	0.0	1.0	H704	0.0	0.0
H800	0.0	0.0	H801	0.0	1.0
H1001	0.0	1.0	H1003	0.0	0.0
H1002	0.0	0.0	H1005	0.0	1.0
H1006	0.0	0.0	H1007	0.0	1.0
H808	0.0	1.0	H601	0.0	1.0
H705	0.0	1.0	H706	0.0	1.0
H707	0.0	1.0	H708	0.0	1.0
H1004	0.0	1.0	C9LNIONC	0.0	1.0

END

Run 3

POWER EXCEEDS SIX MEGAWATTS

RATES

H101	0.0	0.0	H203	0.0	1.0
H202	0.0	0.0	H207	0.0	1.0
H205	0.0	1.0	H206	0.0	0.0
H301	0.0	1.0	H302	0.0	0.0
H303	0.0	1.0	H304	0.0	0.0
H305	0.0	0.0	H306	0.0	1.0
H307	0.0	0.0	H308	0.0	1.0
H401	0.0	0.0	H402	0.0	1.0
H403	0.0	1.0	H404	0.0	0.0
H405	0.0	1.0	H406	0.0	0.0
H407	0.0	1.0	H408	0.0	0.0
H501	0.0	1.0	H502	0.0	0.0
H503	0.0	1.0	H504	0.0	0.0
H505	0.0	1.0	H506	0.0	0.0
H509	0.0	0.0	H507	0.0	1.0
H510	0.0	0.0	H511	0.0	1.0
H602	0.0	1.0	H603	0.0	0.0
H604	0.0	1.0	H605	0.0	0.0
H606	0.0	1.0	H607	0.0	0.0
H701	0.0	1.0	H703	0.0	0.0
H702	0.0	1.0	H704	0.0	0.0
H800	0.0	0.0	H801	0.0	1.0
H1001	0.0	0.0	H1003	0.0	1.0
H1002	0.0	0.0	H1005	0.0	1.0
H1006	0.0	0.0	H1007	0.0	1.0
H808	0.0	1.0	H601	0.0	1.0
H705	0.0	1.0	H706	0.0	1.0
H707	0.0	1.0	H708	0.0	1.0
H1004	0.0	1.0			

END

Run 4

```
POWER REACHES 4.5 MEGAWATTS
/ RATES
H101    0.0     0.0     H203    0.0     1.0
H202    0.0     1.0     H207    0.0     0.0
H205    0.0     1.0     H206    0.0     0.0
H301    0.0     1.0     H302    0.0     0.0
H303    0.0     1.0     H304    0.0     0.0
H305    0.0     0.0     H306    0.0     1.0
H307    0.0     0.0     H308    0.0     1.0
H401    0.0     0.0     H402    0.0     1.0
H403    0.0     1.0     H404    0.0     0.0
H405    0.0     1.0     H405    0.0     0.0
H407    0.0     1.0     H408    0.0     0.0
H501    0.0     1.0     H502    0.0     0.0
H503    0.0     1.0     H504    0.0     0.0
H505    0.0     1.0     H506    0.0     0.0
H509    0.0     0.0     H507    0.0     1.0
H510    0.0     0.0     H511    0.0     1.0
H602    0.0     1.0     H603    0.0     0.0
H604    0.0     1.0     H605    0.0     0.0
H606    0.0     1.0     H607    0.0     0.0
H701    0.0     1.0     H703    0.0     0.0
H702    0.0     1.0     H704    0.0     0.0
H800    0.0     0.0     H801    0.0     1.0
H1001   0.0     1.0     H1003   0.0     0.0
H1002   0.0     0.0     H1005   0.0     1.0
H1006   0.0     0.0     H1007   0.0     1.0
H508    0.0     1.0     H601    0.0     1.0
H705    0.0     1.0     H706    0.0     1.0
H707    0.0     1.0     H708    0.0     1.0
H7004   0.0     1.0
END
```

Run 5

```
     FAST PERIOD SCRAM  LOW POWER
/ RATES
H101    0.0     0.0     H203    0.0     0.0
H202    0.0     1.0     H207    0.0     0.0
H205    0.0     1.0     H206    0.0     0.0
H301    0.0     0.0     H302    0.0     1.0
H303    0.0     0.0     H304    0.0     1.0
H305    0.0     1.0     H306    0.0     0.0
H307    0.0     1.0     H308    0.0     0.0
H401    0.0     1.0     H402    0.0     0.0
H403    0.0     1.0     H404    0.0     0.0
H405    0.0     1.0     H406    0.0     0.0
H407    0.0     1.0     H408    0.0     0.0
H501    0.0     1.0     H502    0.0     0.0
H503    0.0     1.0     H504    0.0     0.0
H505    0.0     1.0     H506    0.0     0.0
H509    0.0     0.0     H507    0.0     1.0
H510    0.0     0.0     H511    0.0     1.0
H602    0.0     1.0     H603    0.0     0.0
H604    0.0     1.0     H605    0.0     0.0
H606    0.0     1.0     H607    0.0     0.0
H701    0.0     0.0     H703    0.0     1.0
H702    0.0     0.0     H704    0.0     1.0
H800    0.0     1.0     H801    0.0     0.0
H1001   0.0     1.0     H1003   0.0     0.0
H1002   0.0     1.0     H1005   0.0     0.0
H1006   0.0     1.0     H1007   0.0     0.0
H508    0.0     1.0     H601    0.0     1.0
H705    0.0     1.0     H706    0.0     1.0
H707    0.0     1.0     H708    0.0     1.0
H1004   0.0     1.0
END
```

Run 6

FAST PERIOD HIGH POWER

RATES					
H101	0.0	0.0	H203	0.0	1.0
H202	0.0	1.0	H207	0.0	0.0
H205	0.0	1.0	H206	0.0	0.0
H301	0.0	0.0	H302	0.0	1.0
H303	0.0	0.0	H304	0.0	1.0
H305	0.0	1.0	H306	0.0	0.0
H307	0.0	1.0	H308	0.0	0.0
H401	0.0	1.0	H402	0.0	0.0
H403	0.0	1.0	H404	0.0	0.0
H405	0.0	1.0	H406	0.0	0.0
H407	0.0	1.0	H408	0.0	0.0
H501	0.0	1.0	H502	0.0	0.0
H503	0.0	1.0	H504	0.0	0.0
H505	0.0	1.0	H506	0.0	0.0
H509	0.0	0.0	H507	0.0	1.0
H510	0.0	0.0	H511	0.0	1.0
H602	0.0	1.0	H603	0.0	0.0
H604	0.0	1.0	H605	0.0	0.0
H606	0.0	1.0	H607	0.0	0.0
H701	0.0	0.0	H703	0.0	1.0
H702	0.0	0.0	H704	0.0	1.0
H800	0.0	0.0	H801	0.0	1.0
H1001	0.0	1.0	H1003	0.0	0.0
H1002	0.0	0.0	H1005	0.0	1.0
H1006	0.0	1.0	H1007	0.0	0.0
H508	0.0	1.0	H601	0.0	1.0
H705	0.0	1.0	H706	0.0	1.0
H707	0.0	1.0	H708	0.0	1.0
H1004	0.0	1.0			

END

Run 15

STARTUP ACCIDENT--SLOW SCRAMS AND FERIOD FAILED--POWER>3MW

/ RATES					
H101	0.0	0.0	H203	0.0	1.0
H202	0.0	1.0	H207	0.0	0.0
H205	0.0	1.0	H206	0.0	0.0
H301	0.0	1.0	H302	0.0	0.0
H303	0.0	1.0	H304	0.0	0.0
H305	0.0	1.0	H306	0.0	0.0
H307	0.0	1.0	H308	0.0	0.0
H401	0.0	1.0	H402	0.0	0.0
H403	0.0	1.0	H404	0.0	0.0
H405	0.0	1.0	H406	0.0	0.0
H407	0.0	1.0	H408	0.0	0.0
H501	0.0	1.0	H502	0.0	0.0
H503	0.0	1.0	H504	0.0	0.0
H505	0.0	1.0	H506	0.0	0.0
H509	0.0	0.0	H507	0.0	1.0
H510	0.0	0.0	H511	0.0	1.0
H602	0.0	1.0	H603	0.0	0.0
H604	0.0	1.0	H605	0.0	0.0
H606	0.0	1.0	H607	0.0	0.0
H701	0.0	1.0	H703	0.0	0.0
H702	0.0	1.0	H704	0.0	0.0
H800	0.0	0.0	H801	0.0	1.0
H1001	0.0	1.0	H1003	0.0	0.0
H1002	0.0	0.0	H1005	0.0	1.0
H1006	0.0	1.0	H1007	0.0	0.0
H508	0.0	1.0	H601	0.0	1.0
H705	0.0	1.0	H706	0.0	1.0
H707	0.0	1.0	H708	0.0	1.0
H1004	0.0	1.0			

END

Run 16

```
STARTUP ACCIDENT--FAIL D200 AND C9LNIONC
' RATES
D200        0.0          1.0    C9LNIONC    0.0          1.0
H101        0.0          0.0    H203        0.0          1.0
H202        0.0          0.0    H207        0.0          1.0
H205        0.0          1.0    H206        0.0          0.0
H301        0.0          0.0    H302        0.0          1.0
H303        0.0          0.0    H304        0.0          1.0
H305        0.0          0.0    H306        0.0          1.0
H307        0.0          0.0    H308        0.0          1.0
H401        0.0          0.0    H402        0.0          1.0
H403        0.0          1.0    H404        0.0          0.0
H405        0.0          1.0    H406        0.0          0.0
H407        0.0          1.0    H408        0.0          0.0
H501        0.0          1.0    H502        0.0          0.0
H503        0.0          1.0    H504        0.0          0.0
H505        0.0          1.0    H506        0.0          0.0
H509        0.0          0.0    H507        0.0          1.0
H510        0.0          0.0    H511        0.0          1.0
H602        0.0          1.0    H603        0.0          0.0
H604        0.0          1.0    H605        0.0          0.0
H606        0.0          1.0    H607        0.0          0.0
H701        0.0          0.0    H703        0.0          1.0
H702        0.0          1.0    H704        0.0          0.0
H800        0.0          0.0    H801        0.0          1.0
H1001       0.0          1.0    H1003       0.0          0.0
H1002       0.0          0.0    H1005       0.0          1.0
H1006       0.0          0.0    H1007       0.0          1.0
H509        0.0          1.0    H601        0.0          1.0
H705        0.0          1.0    H706        0.0          1.0
H707        0.0          1.0    H708        0.0          1.0
H1004       0.0          1.0
END
```

INPUT DECK REPRESENTING THE "AND" AND "OR" GATES
FOUND IN THE FAULT TREE

```
1**********************************************************
 *TREBIL FAULT TREE BUILDING PROGRAM
 **********************************************************


          LPTR FAULT TREE SAFETY ANALYSIS
NUMBER OF GATES,NG----------------------------  230
COMBO STARTING VALUE,MIN----------------------    1
COMBO ENDING VALUE,MAX------------------------    2
CUT SET - PATH SET SWITCH,IDEX1---------------    0
PRINT - PUNCH SWITCH,IDEX2--------------------    0
MONTE CARLO STARTER,MCS-----------------------    0
NO. OF RANDOM NUMBERS TO REJECT,NREJEC--------    0
NO. OF MONTE CARLO TRIALS,NTR-----------------    0
MIXING PARAMETER SWITCH,IREN------------------    0
MONTE CARLO MIXING PARAMETER,TAA-------------        0.
```

```
1**********************************************************
 *TREBIL FAULT TREE BUILDING PROGRAM
 **********************************************************


          LPTR FAULT TREE SAFETY ANALYSIS
NAME      TYPE      INPUTS----
TOP       OR     2 1 G101      G102      D100
G101      AND    3 0 G105A     G105B     G103
G102      AND    3 0 G104      G105C     G105D
G103      OR     2 0 G105C     G105D
G104      OR     2 0 G105A     G105B
G105A     OR     1 1 G106A     D101A
G105B     OR     1 1 G106B     D101B
G105C     OR     1 1 G106C     D101C
G105D     OR     1 1 G106D     D101D
G106A     OR     1 1 G107A     D102A
G106B     OR     1 1 G107B     D102B
G106C     OR     1 1 G107C     D102C
G106D     OR     1 1 G107D     D102D
G107A     AND    2 0 G108A     G109A
G107B     AND    2 0 G108B     G109B
G107C     AND    2 0 G108C     G109C
G107D     AND    2 0 G108D     G109D
G108A     OR     1 1 G200A     D103A
G108B     OR     1 1 G200B     D103B
G108C     OR     1 1 G200C     D103C
G108D     OR     1 1 G200D     D103D
G109A     OR     1 1 G700A     H101
G109B     OR     1 1 G700B     H101
G109C     OR     1 1 G700C     H101
G109D     OR     1 1 G700D     H101
G200A     OR     1 1 G201      D200
G200B     OR     1 1 G201      D200
G200C     OR     1 1 G201      D200
G200D     OR     1 1 G201      D200
G201      OR     1 2 G203      C2PE62-1  C2RE62-2
G203      OR     2 1 G204      G205      D201
G204      AND    2 0 G206      G212
G205      AND    2 0 G206      G210
G206      OR     1 1 G207      D202
G207      AND    2 0 G208      G209
G208      OR     1 1 G300      D203
G209      OR     1 1 G215      H202
G210      AND    1 1 G211      H203
G211      OR     0 2 D204      C2S2-1
G212      OR     1 1 G213      H205
G213      AND    1 1 G214      H206
G214      OR     0 2 C2PCLF    C2RE75-1
G215      AND    1 1 G216      H207
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G216    ON   1 1 G1000    C2RE83-1
G300    AND  2 0 G301     G317
G301    OR   1 1 G302     D300
G302    AND  2 0 G303     G314
G303    OR   1 1 G304     D301
G304    AND  2 0 G305     G311
G305    OR   1 1 G306     D302
G306    AND  2 0 G307     G308
G307    OR   1 1 G400     D303
G308    OR   1 1 G309     H307

G309    AND  1 1 G310     H308
G310    OR   1 1 G900     C3PE81-2
G311    OR   1 1 G312     H305
G312    AND  1 1 G313     H306
G313    OR   1 1 G905     C3PE82-2
G314    OR   1 1 G315     H303
G315    AND  1 1 G316     H304
G316    OR   1 1 G606     C3PE83-1
G317    OR   1 1 G318     H501
G318    AND  1 1 G319     H502
G319    OR   1 1 G811     C3RE84-1
G400    AND  2 0 G401     G417
G401    OR   1 1 G402     D400
G402    AND  2 0 G403     G414
G403    OR   1 1 G404     D401
G404    AND  2 0 G405     G411
G405    OR   1 1 G406     D402
G406    AND  2 0 G407     G408
G407    OR   1 1 G500     D403
G408    OR   1 1 G409     H407
G409    AND  1 1 G410     H408
G410    OR   0 2 C4TROBLC C4PE18-2
G411    OR   1 1 G412     H405
G412    AND  1 1 G413     H406
G413    OR   0 2 C4TROBLD C4PE19-2
G414    OR   1 1 G415     H403
G415    AND  1 1 G416 .   H404
G416    OR   0 3 C4EXSCRM C4COILL32 C4RE32-1
G417    OR   1 1 G418     H401
G418    AND  1 1 G419     H402
G419    OR   1 1 G1100    C4RE88-2
G500    AND  2 0 G501     G518
G501    OR   1 1 G502     D500
G502    AND  2 0 G503     G515
G503    OR   1 1 G504     D501
G504    AND  2 0 G505     G512
G505    OR   2 1 G506     G508      D502
G506    AND  1 1 G507     H507
G507    OR   1 1 G600     D503
G508    AND  1 1 G509     H508
G509    AND  2 0 G510     G511
G510    OR   0 3 H509     H510      H511
G511    OR   0 2 D504     C5PB7
G512    OR   1 1 G513     H505
G513    AND  1 1 G514     H506
G514    OR   0 4 C5RDT    C5SW2-1   C5RE2-2  C5COILR2
G515    OR   1 1 G516     H503
G516    AND  1 1 G517     H504
G517    OR   0 2 C5TROBLA C5RE16-2
G518    OR   1 1 G519     H501
G519    AND  1 1 G520     H502
G520    OR   0 2 C5TROBLB C5RE17-2
G600    AND  2 0 G601     G618
G601    OR   1 1 G602     D601
G602    AND  2 0 G603     G607
G603    OR   1 1 G604     D602
G604    AND  1 1 G605     H601
G605    OR   1 1 G606     H602
G607    OR   1 1 G608     H604
G606    AND  0 2 C6SCRMPB H603
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G608	AND	1	1	G609	H705			
G609	OR	0	3	C61EMPMS	C6CNTL2	C6RE2-1		
G610	OR	1	1	G611	H706			
G611	AND	1	1	G612	H707			
G612	OR	0	3	C6PLLDS	C6CNTL6D	C6PE60-1		
G700A	OR	1	2	G701A	C7MCNTLA	D701A		
G700B	OR	1	2	G701B	C7MCNTLB	D701B		
G700C	OR	1	2	G701C	C7MCNTLC	D701C		
G700D	OR	1	2	G701D	C7MCNTLD	D701D		
G701A	OR	3	0	G702A	G703A	G704A		
G701B	OR	3	0	G702B	G703B	G704B		
G701C	OR	3	0	G702C	G703C	G704C		
G701D	OR	3	0	G702D	G703D	G704D		
G702A	AND	1	2	G705A	H701	H702		
G702B	AND	1	2	G705B	H701	H702		
G702C	AND	1	2	G705C	H701	H702		
G702D	AND	1	2	G705D	H701	H702		
G703A	AND	1	2	G706A	H702	H703		
G703B	AND	1	2	G706B	H702	H703		
G703C	AND	1	2	G706C	H702	H703		
G703D	AND	1	2	G706D	H702	H703		
G704A	AND	1	2	G707A	H703	H704		
G704B	AND	1	2	G707B	H703	H704		
G704C	AND	1	2	G707C	H703	H704		
G704D	AND	1	2	G707D	H703	H704		
G705A	OR	1	2	G708	C7MAMPA	D702		
G705B	OR	1	2	G708	C7MBMPB	D702		
G705C	OR	1	2	G708	C7MCMPC	D702		
G705D	OR	1	2	G708	C7MDMPD	D702		
G706A	OR	1	2	G709	C7MAMPA	D702		
G706B	OR	1	2	G709	C7MBMPB	D702		
G706C	OR	1	2	G709	C7MCMPC	D702		
G706D	OR	1	2	G709	C7MDMPD	D702		
G707A	OR	1	2	G710	C7MAMPA	D702		
G707B	OR	1	2	G710	C7MBMPB	D702		
G707C	OR	1	2	G710	C7MCMPC	D702		
G707D	OR	1	2	G710	C7MDMPD	D702		
G708	AND	3	1	G711	G715	G719	H705	
G709	AND	4	0	G711	G715	G719	G800	
G710	AND	1	3	G800	H706	H707	H708	
G711	OR	1	2	G712	D705	D704		
G712	OR	2	1	G713	D705			
G713	OR	1	1	G714	H706			
G714	OR	0	2	C7IONCHA	D707			
G715	OR	1	2	G716	D709	D710		
G716	OR	1	1	G717	D711			
G717	OR	1	1	G718	D712			
G718	OR	0	2	C7IONCHB	D713			
G719	OR	1	2	G720	D715	D716		
G720	OR	1	1	G721	D717			
G721	OR	1	1	G722	D718			
G722	OR	0	2	C7IONCHC	D719			
G800	OR	1	2	G801	D000	D801		
G801	OR	1	1	G802	D802			
G802	OR	1	1	G803	D803			
G803	OR	1	1	G804	D804			
G804	OR	1	2	G805	C8S15BYP	D805		
G805	OR	1	1	G1019	D806			
G806	OR	1	1	G807	D807			
G807	OR	1	1	G808	C8RE24-1			
G808	OR	1	1	G809	D808			
G809	OR	1	1	G810	C8CLKD			
G810	OR	1	1	G802	D009			
G811	OR	2	1	G812	G813	D810		
G812	OR	0	2	C8S16BYP	D811			
G813	OR	1	1	G814	C8S1PERR			
G814	OR	1	1	G815	C8CLRREC			
G815	OR	2	0	G816	G818			
G816	AND	1	1	G817	H800			
G817	OR	0	4	C8LCR5YS	C8S18YP5	D812	D813	
G818	AND	1	1	G819	H801			
G819	OR	1	3	G1019	C8S18YP5	D813	D814	
G900	OR	1	1	G901	D501			

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G901     OR    1 1 G902     C9PL22-1
G902     OR    1 1 G903     D901
G903     OR    1 1 G904     C9SLCB
G904     OR    1 1 G717     D903
G905     OR    1 1 C90E     D904
G906     OR    1 1 G907     C9PL23-1
G907     OR    1 1 G906     D905
G908     OR    1 1 G909     C9SLCC
G909     OR    1 1 G721     D906
G910     OR    1 2 G911     C9LLPEC  D914
G911     OR    1 1 G912     D907
G912     OR    1 1 G913     C9UUAMTR
G913     OR    1 2 G914     C9LLIONC D908
G914     OR    0 2 D909     D910
G915     OR    1 2 G916     C9LHIONC D911
G916     OR    0 2 D912     D913
G1000    OR    2 1 G1001    G1002    D1000
G1001    AND   2 0 G1003    G1004
G1002    AND   2 0 G1005    G1006
G1003    OR    1 1 G1007    H1001
G1004    OR    1 1 G1008    D1001
G1005    OR    1 1 G1009    D1002
G1006    OR    1 1 G1010    H1002
G1007    AND   1 1 G1011    H1003
G1008    AND   1 1 G1012    H1004
G1009    AND   2 0 G1012    G1013
G1010    AND   1 1 G1014    H1005
G1011    OR    1 1 G1015    C10S2PLR
G1012    OR    1 1 G1016    D1003
G1013    OR    1 3 G1021    C10P86-2 C10P86C0 D1004
G1014    OR    1 1 G1015    C10S3LNR
G1015    OR    1 1 G1017    C10LOGNR
G1016    OR    1 1 G1018    H1006
G1017    OR    1 1 G1019    D1007
G1018    AND   1 1 G1020    H1007
G1019    OR    1 1 G915     C10LNPPR
G1020    OR    1 1 G910     C10S2LLR
G1021    OR    1 1 G1022    D1005
G1022    OR    0 2 C10S14   D1006
G1100    OR    1 1 G1101    D1101
G1101    OR    1 1 G1102    C11R2I-1
G1102    OR    1 1 G1103    D1102
G1103    OR    1 1 G1104    C11SLCA
G1104    OR    1 1 G713     D1103
END           -0-0
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